Integration of Process Planning and Scheduling in the Manufacturing Sector to Enhance Productivity – a Case study of Developing Countries

By

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This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purpose (unless otherwise indicated). Save for any express acknowledgments, references and/or bibliographies cited in the work, I confirm that the intellectual content of the work is the result of my own efforts and of no other person.

Signature: McCarthy Emeka Bryan

Date: May 2018

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List of abbreviations

CAPP	Computer-Aided Process Planning
CLA	Closed Loop Approach
CPG Ltd	CPG Ltd is a fictitious name used in this thesis to preserve confidentiality and anonymity of the participating manufacturing company and individuals
DA	Distributed Approach
EC-FIKT	Effective Communication through Facilitated Information and Knowledge Transfer
ERP	Enterprise Resource Planning
IKT	Information and Knowledge Transfer
IPPS	Integration of Process Planning and Scheduling
IS	Information systems
MES	Manufacturing Execution System
MRP	Material Requirements Planning
MS	Manufacturing System
NLA	Non-Linear Approach
RQ	Research question
PS	Production Scheduling
SAP	Structural Adjustment Programme
SCM	Supply Chain Management
SMcorp	SMcorp is a fictitious name used in this thesis to preserve confidentiality and anonymity of the participating manufacturing company and individuals
SMED	Single-minute exchange of dies
SPC	Statistical Process Control

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Abstract

This thesis describes research carried out to investigate and address the problems associated with integration of process planning and scheduling through collaboration between diverse functions within manufacturing companies in Nigeria. Collaboration is an emerging necessity for functions of manufacturing companies in developing countries and has been influenced by the evolving need for gathering segmented groups with diverse knowledge and experience in developing new solutions to support addressing complex problems in a domain. Use of new technologies, to some extent, assists interaction and collaboration between segregated functions. This approach has been a feasible solution for real-time communication in virtual environment, however, functional boundaries influence the recognition of the problem-related factors affecting different functions in a domain and results in conflicts of perspectives and ineffective interaction between functions.

The study carried out here investigated the limitations of existing approaches to manufacturing with a view to engaging segregated functions by integration of process planning and scheduling functions and thereby develop a new approach to address a key manufacturing company's complex problem. Consequently, this thesis addresses the research question ***"****How do we minimise the limitations to existing manufacturing approaches which integrate process planning and scheduling in developing countries?"*. In doing so, this research brings together current literature on manufacturing systems and empirical evidence to investigate the factors that influence the effectiveness of integration of process planning and scheduling through collaborations with different functions. Review of the existing approaches to integration of process planning and scheduling and the limitations of each approach shows that the effectiveness of this integration has not been fully achieved. This resulted in developing, refining and validating a new approach to integration of process planning and scheduling which was applied in different manufacturing companies.

The study resulted in significant contributions to knowledge and benefits for the manufacturing companies involved. A key contribution is development of a new approach to integration of process planning and scheduling called EC-FIKT which emphasises Effective Communication through Facilitated Information and Knowledge Transfer. The applications of EC-FIKT in the field suggest that it eliminates some of the main deficiencies of well-known approaches to integration of process planning and scheduling, and which brings additional benefits to manufacturing companies. The research has also identified areas where there is significant scope for further research and investigation.

I dedicate this thesis to the AMAZING GRACE and LOVE of GOD that helped me to start, continue and successfully complete this PhD programme.

CHAPTER ONE

1. INTRODUCTION

Information transfer and collaborations between process planning and production scheduling functions has gained significant importance in manufacturing industry. The importance of intra-organisational relationships between these two departments for improving the productivity of manufacturing industry in developing countries has become inevitable as the overall performance of the manufacturing companies relies on involvement and performance of these two segregated functions. Because of this lack of intra-organisational relationships, the information base of segregated departments within manufacturing, to some extent, has become fragmented into separate, specialised information domain. Due to such factors, information transfer and collaborations between these departments has become more complex.

This research has been undertaken to understand the challenges associated with integration of process planning and scheduling and to develop a new approach to address some of the key challenges. This chapter includes an introduction to the context of the research, the challenges associated with integration of process planning and scheduling and the proposed approach.

1.1. Introductory remarks

This thesis conveys the research conducted in the field of manufacturing system (MS) with emphasise on MS activities, in particular, process planning and production scheduling activities within the framework of manufacturing productivity. Its focus is on integration of process planning and scheduling (IPPS) within manufacturing industry in developing countries. The utility of this research is to clarify problematic aspects of IPPS through the analysis of real cases of manufacturing industry in Nigeria with the aim to develop a new approach to IPPS that is effective in terms of improving manufacturing productivity. Zhang *et*

al. (2016) clarify that effective process planning and production scheduling have significant influence on saving energy, reducing manufacturing cost and protecting the environment. Therefore, integrative approach to manufacturing process has significant potential benefits for the concerned manufacturing industry, however, some limitations influence the practicability of this approach.

The effectiveness and success of integrating process planning and scheduling has been limited by a number of issues that are as follows:

– Diversity of goals, information and decisions

  Ciurana *et al*. (2008) inform that the goals, information and decisions taken in process planning and production scheduling, in particular, are often very different which develop the difficult challenges associated with integrating them.

– Different process planning and production scheduling departments within manufacturing industry

  Phanden *et al*. (2011) explains that reorganising the work of process planning and production scheduling departments can assist merging the two departments to improve productivity, however, Phanden *et al*. (2013) clarify that the challenges associated with dismantling and reorganising existing process planning and production scheduling departments are significant.

This research revolves around better understanding of the challenges associated with integration of process planning and scheduling, the limitations of existing approaches that address some of these challenges and developing a new approach to address some of those limitations. The new approach covers the factors that affect the effectiveness and success of engaging process planning and production scheduling functions in collaboratively transfer information across departmental boundaries. Some of the key aspects of the new approach are validated through its application in major manufacturing industry in Nigeria. Moreover, this thesis identifies and presents the areas that have significant scope for further research.

The remainder of this chapter describes the foundation and development of the research reported in this thesis. This chapter includes the description of the research problem and summary of the proposed approach that addressed the challenges associated with integration

of process planning and scheduling in developing countries followed by the outline of the thesis.

1.2. Research context

1.2.1. Productivity of manufacturing industry in developing countries

One of the primary goals of most manufacturing companies, especially in the presently challenging economic conditions, is the ability to operate with an improved productivity level. This is because productivity serves as a useful instrument for determining the level of business performance of any manufacturing company. When measured regularly, productivity also assesses the efficiency, competitiveness and rate of growth of an economy (i.e. business organisation, industrial sector or nation).

Considering the high population of Nigeria and the market size it presents, manufacturing industries in Nigeria therefore have a key role to play in ensuring they live up to their calling and this means increasing the levels of their productivity. Essentially, productivity is a ratio that measures how well a productive unit (either an individual, business organisation or country) is able to convert input resources (labour, materials, machines etc.) into products and services through its production processes. Literature on manufacturing industries in most developing countries suggests that productivity levels are very low. Eti *et al.* (2004), report that many industries in Nigeria operate productively for less that than 50% of even the nominally functioning hours per year. They explain that part of this problem is caused by excessive downtime, supply failures for input resources, and low spare-capacity to cope with sudden high demands.

One route to achieving a better manufacturing productivity is through a better manufacturing process planning, backed up by an efficient and effective execution at the shop floor. Both processes must be interfaced to ensure that an improved productivity is attained through operational efficiency. Duran *et al.* (2015) define operational efficiency as an indicator for revealing the level of effectiveness in using production resources such as raw materials and supplies, manpower, land, building, machine, equipment and energy. Kinda *et al*. (2011) clarify that because developing countries face both increasing pressure of globalisation and buoyant growth of the labour force, productivity in manufacturing is central to international competitiveness for them.

The above discourse shows that efforts have been made in many industries to inculcate processes that will lead to increased efficiency and leading to productivity improvements. In the manufacturing industry, this has led to many approaches or theories which are adopted to ensure process waste is reduced while improving the quality of outcomes. Duran *et al.* (2015) inform that one common approach is work study, which aims at examining the way an activity is being carried out, simplifying or modifying the method of operation to reduce unnecessary or excess work, or the wasteful use of resources and setting up a time standard for performing that activity.

In the context of productivity improvement in manufacturing industries, this research focuses on investigating measures to improve the productivity of manufacturing industries in Nigeria through manufacturing process improvements.

1.2.2. The concept of integration of process planning and scheduling

Effective integration of process planning and scheduling has been identified as one important route to achieve an improved manufacturing productivity. Shen *et al*. (2006) describes manufacturing process planning as dealing with the selection of the various operations or processes required to be performed in sequence in order to transform raw materials to semi-finished or finished goods, in accordance to the design specifications, while the production scheduling aspect is seen as concerned with the execution of the outcome of the process planning. Therefore, the improvement of the operational efficiency relies to a large extent on process improvement. Sutari (2015) explain that process improvement is the systematic approach to closing of process or system performance gaps through streamlining and cycle time reduction, and identification and elimination of causes of below specifications quality, process variation, and non-value adding activities. Conducting process improvement will help give an advantage to any manufacturing company.

Rapid developments in computerized manufacturing environments and increasing overlapping in the capability of manufacturing resources provoked integration of many manufacturing functions including process planning and production scheduling (Baykasoglu and Özbakır, 2009). Liu *et al*. (2014) inform that dynamic manufacturing environments require a flexible process planning and control system in response to changing manufacturing resource availability, production uncertainty, and dynamic machining conditions. Production schedule, materials movement planning and process layout design are the important components of manufacturing system.

1.2.3. Historical development of IPPS

Integration of manufacturing functions has been an emerging extension of lean manufacturing theories that has been influenced by the evolving need for developing tools and techniques to discover potential saving patterns such as optimal use of resources or reducing the total length of the schedule. Conventional approaches to process planning and production scheduling consists of separate phases through which production scheduling is done separately and, in particular, after the process planning. Use of technologies, to some extent, facilitates the integration of process planning and scheduling functions, however, the limitations of technology-based approaches have negative influence on the effectiveness and success of the integration. In addition to some of the problems – such as fixed process plans (Phanden *et al*., 2011) – related to conventional approaches, the key challenges associated with existing computer-supported approaches are one-way integration and complexity of re-planning and re-scheduling (Tan and Khoshnevis, 2000). Therefore, lack of intra-organisational relationships between these two departments develops the boundary between them which creates the issues related to two-way information and knowledge transfer (IKT) between the departments and the need for engaging them in collaborative work. Consequently, collaboration between process planning and production scheduling function has a significant impact on the effectiveness and success of IPPS.

1.2.4. Technology-based versus people-based approaches to IPPS

Data-centric collaboration approach can rely on virtual information and computational environment that support data sharing (Chin and Lansing 2004). This approach has been a feasible solution for real-time communication in virtual environment, however, problem-centred approach, requires real environment that facilitates real-life interaction and information and knowledge transfer. Creating and maintaining an environment for information and knowledge transfer demands facilitation experts to hold an environment for the concerned members of process planning and production scheduling functions, co-creating solutions around agreed problems.

1.3. Research problem

1.3.1. The definition of research problem

Panizzolo *et al*. (2012) explain that transforming manufacturing process from conventional low-cost and labour- intensive into more flexible and more productive manufacturing process has gained particular importance in developing countries, since 1990. Kinda *et al.* (2011) and Oguntoye and Evans (2017) remark that in developing countries, in particular Nigeria in Africa, industrial reports and surveys reveal that importance of improving manufacturing productivity and sustainability is significant in the context of development for such countries. Mama (2016) reports that for the Nigeria it has become critical to replace oil and gas with manufacturing and agribusiness to survive the impacts of falling oil prices, however, destructive impacts of Nigeria's power generation crises and many other problems on manufacturing has been inevitable for the last two decades.

SMcorp, one of the leading manufacturing companies based in Nigeria, has to improve its productivity, simultaneously reducing its energy consumption. The key factors that influence the origin of SMcorp's problem is illustrated in Figure 1-1 (SMcorp is a fictitious name used in this thesis to preserve confidentiality and anonymity of the participating manufacturing company and individuals)

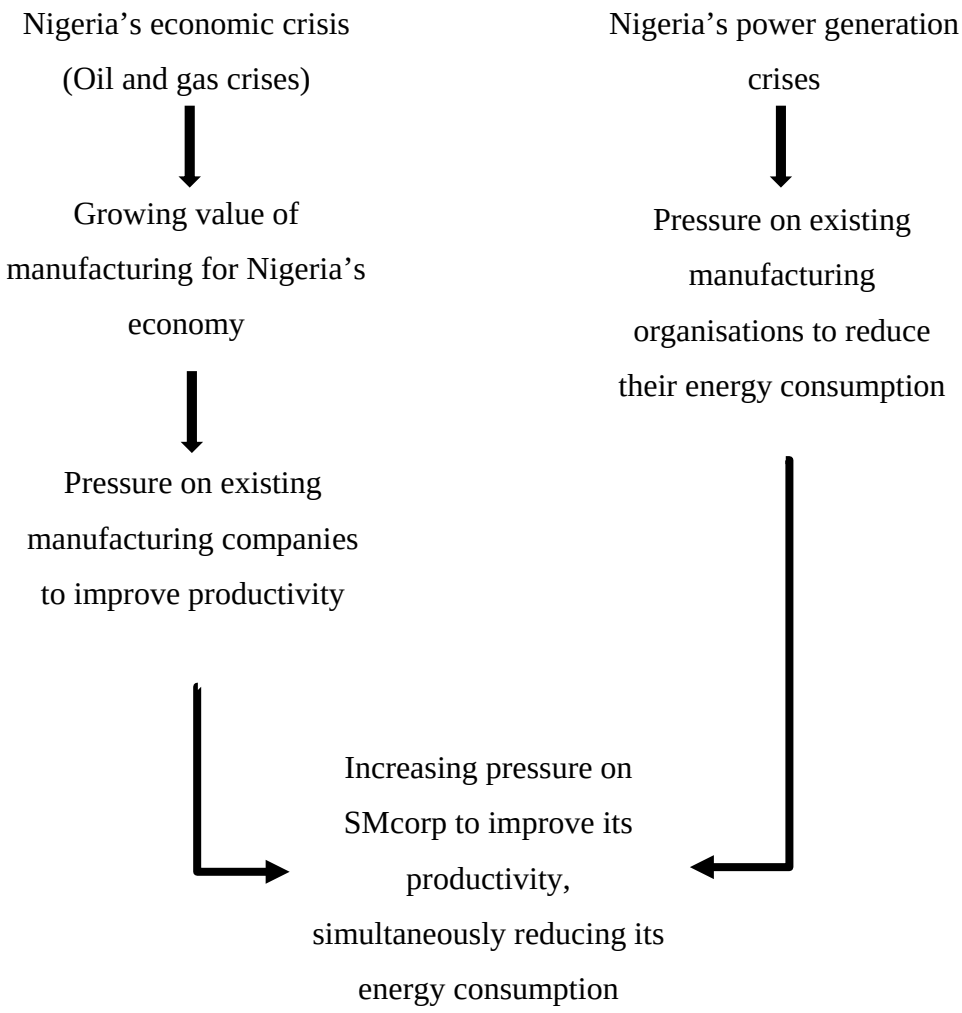

Figure 1-1. The key factors influencing the origin of SMcorp's problem

In response to addressing SMcorp, this manufacturing company demanded academic research which resulted in collaboration between the researcher and SMcorp that formed the beginning of the new approach to IPPS reported in this thesis. This thesis refers to this collaboration as SMcorp project. This was an opportunity to get involved in a IPPS project within a metal building manufacturer in 2014. The twofold aims of this project are as follows:

- Information and knowledge about delays on the shop floor was to be collected from production scheduling experts and transferred to a number of engineers in the process planning function

- A system was to be produced with the aim of helping the manufacturing company to study whether collaborative delay diagnosis on the shop floor could reduce the workload of production scheduling experts.

The two aims were addressed in a combined manner. Facilitated by the researcher, production scheduling experts and engineers from the shop floor were involved in the collaborative development of models of delay diagnosis, discussing their symptoms, root causes and probabilities. Those models took the forms of Bayesian network modelling (as a directed acyclic graphical model).

1.3.2. The research questions

The researcher conducted a review of the existing theories on IPPS during and after the SMcorp project. The combination of theory and primary data collected during this project on IPPS resulted in defining the primary research question that is as follows:

> ***How do we minimise the limitations to existing approaches to integrate process planning and scheduling in developing countries?***

The primary research question highlights the complexities of the problem which clarifies that addressing the limitations of existing approaches to integration of process planning and scheduling requires research in a number of areas that are as follows:

- The existing approaches to integration of process planning and scheduling
- The methods of evaluating the success of those approaches
- The efficiency and limitations of the approaches

The importance of investigating these factors, driven from the primary research question, demonstrates the need for defining a number of additional research questions (RQ) that have to be answered, to some extent, in this research.

The additional research questions were defined as follows:

> *RQ.1. What does the concept of integration of process planning and scheduling mean?*
>
> *RQ.2. What is the relationship between manufacturing productivity and integration of process planning and scheduling?*

RQ.3. What is the relationship between group dynamics and success of integration of process planning and scheduling?

RQ.4. What is the role of technology in the process of integration of process planning and scheduling?

RQ.5. How can effectiveness and success of the integration of process planning and scheduling be assessed?

The researcher will address the additional questions to the extent that facilitates addressing the primary research question as the scope of this thesis confines finding definitive answers for the additional questions.

1.4. The research aim and objectives

SMcorp project, during early stages of this research, identifies the research problem followed by defining the aim of this research as follows:

The definition and validation of a new approach to integrate process planning and scheduling thereby address some of the key limitations of existing approaches to IPPS.

In order to achieve this aim, the following objectives were defined as follows:

1. Review the development of the concept of IPP, the limitations it has encountered and defining the concept of 'integration of process planning and scheduling' that is referred to in this research
2. Review the key areas emerged from the early stages of SMcorp project in this research that facilitated the development of a new approach to IPPS
3. Investigate the existing approaches to integration of process planning and scheduling
4. Define and implement a new approach to IPPS in developing countries that address the key limitations of existing approaches
5. Draw and verify conclusions on the validity of the new approach to IPPS according to the data collected from manufacturing industry in developing countries

1.5. Research contribution

The collaboration with SMcorp that initiated the research reported in this thesis and collaboration with other manufacturing companies in Nigeria delivered benefits for the parties involved and in particular for the researcher and the manufacturing companies itself. Therefore, this research provides theoretical and practical contributions to the field of manufacturing system. The following presents the summary of key contributions of this research:

1. Contribution to the theory. The contribution of this research to theory is assisting the existing literature by addressing the key gaps in the process of the integration of process planning and scheduling

2. Contribution to the empirical context. The findings of this research address the limited empirical research at manufacturing companies and at manufacturing industry level in the area of integration of process planning and scheduling

3. Contribution to practice: the collaboration between the researcher and manufacturing companies, resulted in better understanding of the importance of integration of process planning and scheduling for the manufacturing companies in terms of improving their performance and manufacturing productivity

1.6. Outline of the thesis

The topic of integration of process planning and scheduling and the outline of the research problem have been presented in this first chapter. The remainder of the thesis is structured in three parts.

The first part of this thesis comprises two chapters that are chapter two and chapter three. Chapter two describes the concept of integration of process planning and scheduling. It includes the investigation of the existing approaches that focused on addressing challenges associated with improving manufacturing productivity and saving energy through IPPS followed by lessons learned from implementing of the approaches in different manufacturing domains. In addition, this chapter includes a review of key topics that have influenced the development of the new approach to integration of process planning and scheduling in this research. Chapter three describes the research methodology that has been used in this research to address the research problem.

The second part of the thesis presents the proposed approach to integration of process planning and scheduling. It covers the development and applications of the new approach to integration of process planning and scheduling in two chapters that are chapter four and five. Chapter four presents the origins of identifying the new approach to IPPS and describes its implementation in developing countries. Chapter five describes the applications of the new approach to IPPS.

The focus of the third part of the thesis is on assessment of the new approach to IPPS. Chapter six presents the analysis of the primary data collected during the conduct of this research and discusses the quality of the findings of this research. This chapter describes the process of reducing the large volume of primary data collected from real manufacturing companies in Nigeria.

The summary of key contributions of the research, concluding remarks and list of the areas that will benefit from further research are presented in chapter seven.

The outline of the thesis structure is illustrated in Figure 1-2.

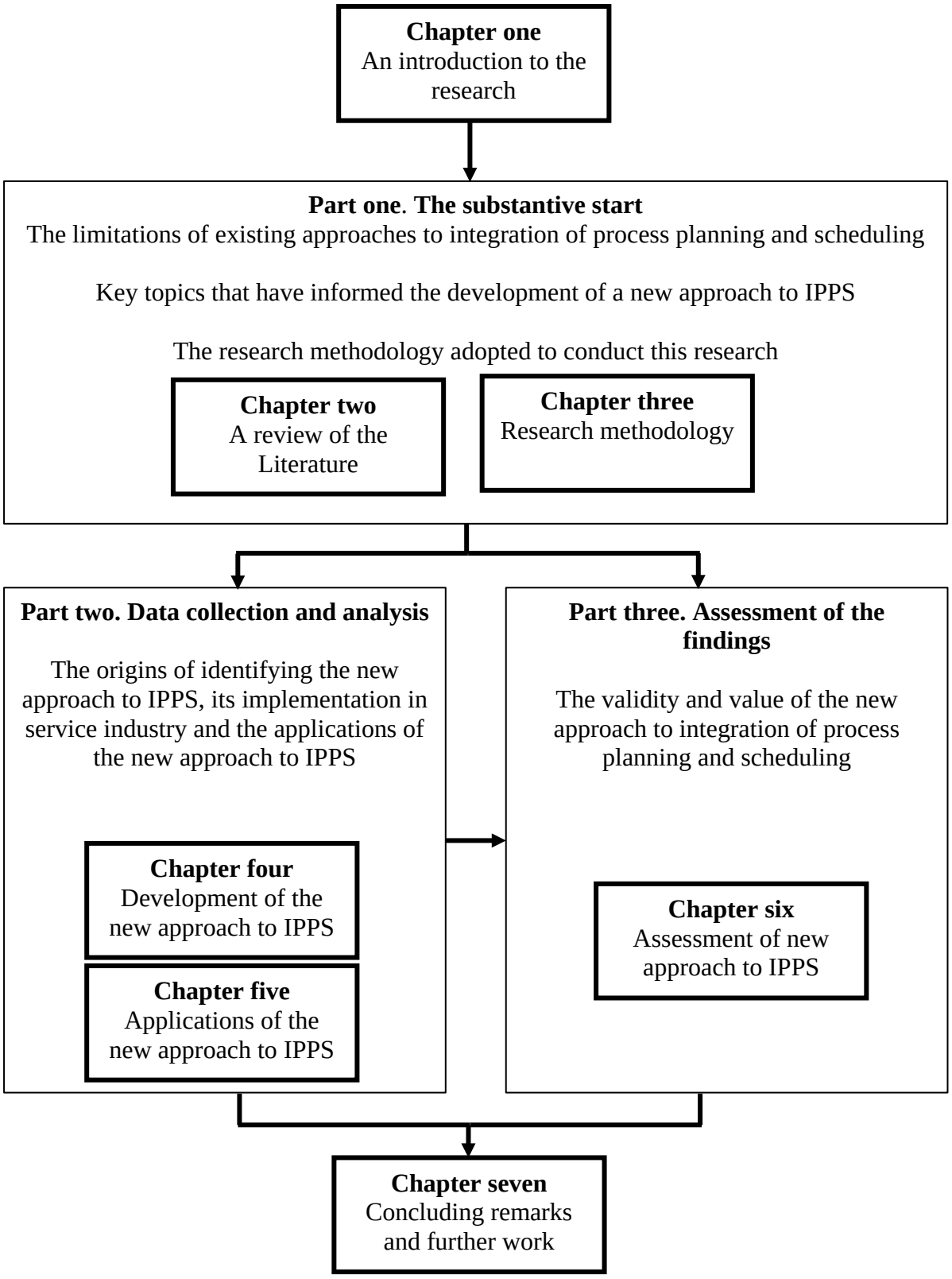

Figure 1-2. Outline of the thesis structure

CHAPTER TWO

2. LITERATURE REVIEW

This chapter presents its focus in the first section followed by a brief review of the emergence of integration of process planning and scheduling in the second section. In order to address the issues related to intra-organisational relationships between process planning and production scheduling functions, the third section of this chapter includes a review of the literature that assists this research in investigating the key factors that have significant impact on effectiveness and success of integration of process planning and scheduling. The aim of this investigation – the importance of this investigation for the development and assessment of a new approach to integration of process planning and scheduling is considerable – is to present the key factors that have to be considered, by a fresh attempt, to address the limitations that existing approaches to integration of process planning and scheduling have encountered. Moreover, this chapter includes a review of the key areas emerged from the early stages of collaboration with a leading manufacturing company in this research with emphasise on improving productivity that is potentially informative for the development of a new approach to integration of process planning and scheduling.

2.1. The focus of the literature review

The research reported in this thesis originated from the need to investigate the limitations of existing approaches to integration of process planning and scheduling in developing countries in order to understand the areas that need improvement which can assist the improvement of manufacturing productivity and energy savings. This has defined the research problem (Discussed in chapter one, section 1.3). Therefore, the literature review presented in this chapter reviews the existing research in the area of IPPS in different domains to provide a

background on the issues related to IPPS. Consequently, this literature review aims to present the factors as follows:

- Identify the key area that have been encountering the challenges associated with separate work of process planning and production scheduling functions, in particular, where integration of process planning and scheduling is required
- Investigate the limitations of existing approaches to IPPS to assist the development of a new approach to IPPS in developing countries that address some of these limitations
- Investigate the methods that assists evaluation of the success of the new approach to IPPS

In order to do so, this chapter continues with reviewing the literature that informed the development of a new approach to integration of process planning and scheduling.

2.2. The emergence of the integration of process planning and scheduling

Early in the 1990s, the concept of 'integration of process planning and scheduling' has gained considerable research attention (Tan and Khoshnevis, 2000).

Sola *et al*. (2013) inform that the influence of the collapse of the oil market in the early 1980s, introduced a problem related to shifting from oil-dependent economy to improving Nigeria economy through performance of the manufacturing industry of Nigeria. This was followed by the change in energy pricing in Nigeria – introduced by the structural adjustment programme (SAP) in 1986 (Adenikinju, 1998) - to reduce the high support of crude oil as the major foreign earner for the economy, through promoting non-oil exports such as manufactured products. Danmaraya and Hassan (2016) affirm that, for the last three decades, addressing the manufacturing productivity through reducing energy consumption such as electricity, in Nigeria, has become the focus of many of firms in manufacturing industry of this developing country.

Following on from the definitions outlined in chapter one, section 1.3, Zhang and Mallur (1994) explain that functional integration of the functions in a manufacturing system has become necessary for maintaining productive shop floor and the integration of process planning and scheduling functions is not an exception. They affirm that although development of the individual functions is important, it does not influence the productivity as much as the integration of process planning and scheduling. Zhang and Malbur's (1994) view

defines the key topic to consider while analysing the IPPS problem. This is the feasibility of collaboration between the process planning and scheduling functions.

In the field of manufacturing system Wang *et al.* (2007) define that *process planning* is a knowledge-intensive and complex task that supports the process of transforming design information into manufacturing processes which determines the most reliable sequence of operations. Chan and Chung (2007) clarify that a good schedule has significant influence on the efficiency of manufacturing system. However, developing a good schedule is difficult and time-consuming activity.

In addition to manufacturing system, however, there are other areas that have focused on integrating process planning and scheduling functions. The review of the literature carried out on this topic and the analysis of the domain of integration of process planning and scheduling clarify that such areas appear to fall into five key categories that are as follows:

- Information systems: The development of information systems (IS) is a key factor that interacts with the process of integration of process planning and scheduling. Kim *et al*. emphasise that there is a significant relationship between the effectiveness of IS and the impact of information flow between internal functions of an organisation. Therefore, effectiveness of IS has inevitable impact on the success of IPPS in terms of manufacturing productivity
- Operations management: The literature reflects the confusion associated with the definition of operations management as compared to the functional management of production. At the fundamental level, operations management has been associated with issues such as aggregate planning, capacity planning, facility design and location, forecasting, maintenance, manpower scheduling, process design, project management, quality of work life, job scheduling, and work measurement (Sahin and Robinson Jr, 2005). Therefore, operations management can be defined as: applying analytical tools and frameworks to improve manufacturing processes across internal functional boundaries.
- Lean manufacturing: Lean manufacturing assists the manufacturing companies to eliminate waste from the product flaws, processing waste, motion waste, waste linked to waiting time, inventory waste, transportation waste and overproduction waste (Rahman *et al*., 2013). Therefore, there is a significant relationship between lean manufacturing and manufacturing productivity.

- Supply chain management: One definition of supply chain management (SCM) is offered by La Londe (1998) as: *the delivery of enhanced customer and economic value through synchronised management of the flow of physical goods and associated information from sourcing through consumption.* A narrower discipline that focuses on the movement and storage of material through SCM is *logistics* which is defined by Christopher (2016) as: *the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximized through the cost effective fulfilment of orders*. Agnetis *et al*. (2017) affirms that SCM revolves around organisational restructuring, extended to the achievement of a company-wide collaborative culture.
- Collaborative leadership. Schwarz (2002) emphasises that in this approach the skilled collaborative leader is skilled in process, expert in content and involved in decision-making and these characteristics constitute collaborative leader.

The remainder of this chapter will review some of the key challenges associated with the process of integration of processes planning and scheduling that is built on the analysis of the key areas outlined above.

2.3. Integration of process planning and scheduling in a manufacturing system

2.3.1. Foundation of manufacturing system

Stein (2003) informs that a major step forwards in manufacturing industry was introduced through the advent of the computer which has been facilitating the process of storing, influencing and employing large volume of data followed by developing and supporting the demand for upper level finished goods items, drive demand for lower level assemblies and raw material parts, and schedule the shop floor. He highlight that the closed loop system, illustrated in Figure 2-1, became the most recognised graphic of the manufacturing systems industry by the end of 1970s and early 1980s.

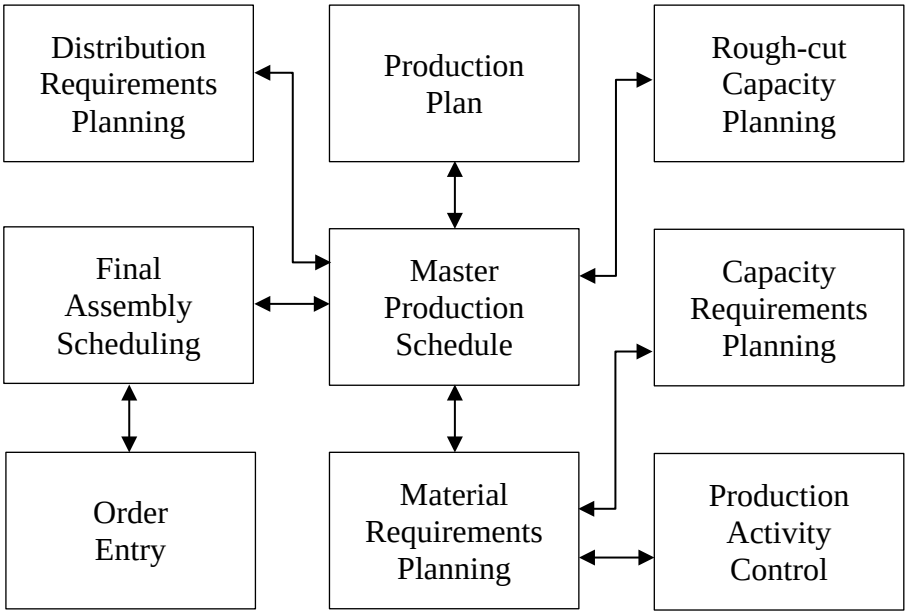

Figure 2-1. The closed loop system of manufacturing industry system (Stein, 2003)

Scallan (2003) explains the characteristics of manufacturing systems in four categories that are as follows:

- All manufacturing systems have to address certain business-related objectives in the most cost-effective manner

- All manufacturing systems consist of an integrated set of sub-systems, which is mostly relevant to the functions. The pattern of linking these sub-systems is based on the material processing
- All manufacturing systems control both the sub-systems and the overall system to a certain extent
- All manufacturing systems demand a flow of information and decision-making process in order to operate efficiently

The relationship between sub-systems of manufacturing system is illustrated in Figure 2-2.

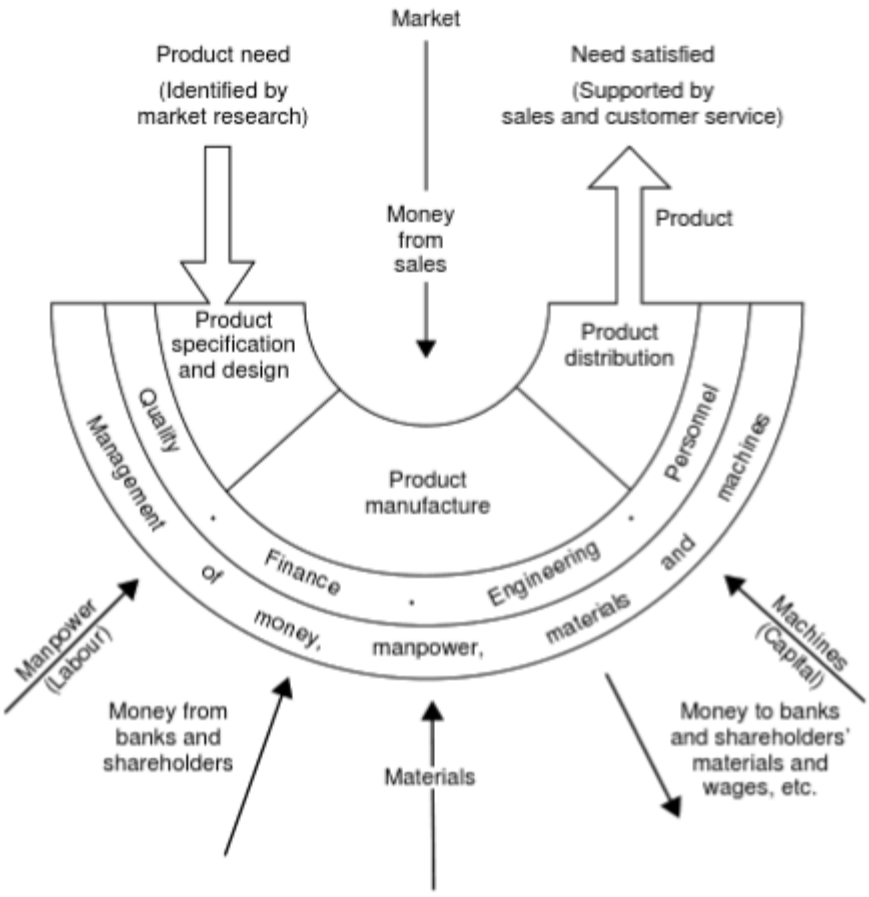

Figure 2-2. The manufacturing system (Mair, 1993)

2.3.2. Process planning function in the manufacturing system context

Manufacturing process planning is both an integral component as well as a crucial aspect to the advancement of the manufacturing industry (Shojaeipour, 2015). Process planning is needed for the setup of manufacturing plants that produce everyday products. Process planning deals with the selection of necessary manufacturing processes and determination of

their sequences, as well as the selection of manufacturing resources to transform a design model into a physical component economically and competitively (Xu *et al*., 2011). The aim of process control is to take actions to the changing manufacturing environments and machining conditions to guarantee manufacturing quality and efficiency (Liu *et al*., 2014), where monitoring and inspection approaches are always involved (Teti *et al*., 2010).

The industrial inputs flow through many steps for transforming completely into products. In each and every step, the inputs are deformed and get new shape and size due to actions of supplied energy, worked done by the machineries and labour forces under the controlling of knowledge-based operations. The mechanics of this transformation are known to be the manufacturing process and the variables involve in the process such as energy, supplied amount of work, skills and technology are known to be process variables.

Scientific literatures provide many ways of understanding manufacturing process but commonly it says that the manufacturing process is a few sequential steps and operations as shown in Figure 2-3. Additionally, for designing an efficient manufacturing operation sufficient experimental data are also required to ensure that manufacturing system can consistently provide outputs. However, the input variables, the transformation efficiency, from inputs to outputs, is largely dependent on the components of process variables. Manufacturing literatures have shown a few critical components associated with the process variables on which the transformation efficiency is largely dependent. These vital components are: production planning and scheduling, controlling the inputs flow through process, maintaining the quality of inputs and optimisation of the process layout. Identifying and removing non-value-added inputs from manufacturing process and optimising production cycle time are also regarded as the dominant controlling variables on which manufacturing performance is significantly dependent.

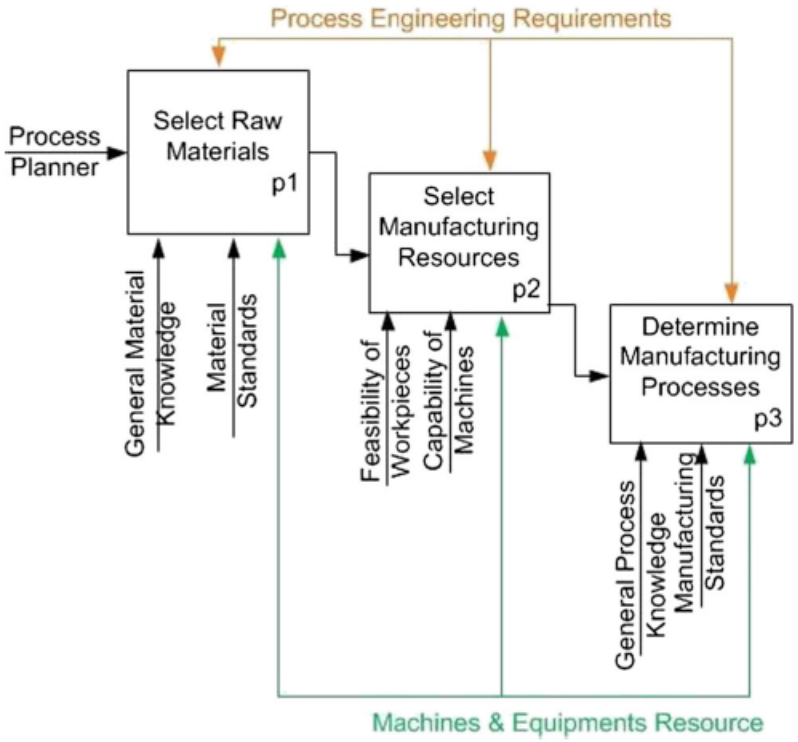

Figure 2-3. Information requirements for preliminary process planning (Shojaeipour, 2015)

At the shop floor level, changes of manufacturing resource availability induced by machine tool failures or emergent orders always enforce the process planning department to conduct process preplanning in order to adapt to these changes, which is very time consuming and costly (Safaieh *et al*., 2013). At the machining level, various machining problems may emerge during the machining process due to complex machining conditions. The changing machining conditions such as spindle thermal deformation, tool failure, chatter, and work-piece deformation induced by clamping force, cutting force, and material inner stress (Ramesh *et al.*, 2000) have significant impacts on machining quality and efficiency. The integration of machining process planning and scheduling is always required to improve the subsequent machining process (Wosnik *et al*., 2009), and the process control information can be used as reliable source of knowledge for process planning.

Various information models based on features and existing standards have been proposed and developed in the literature to facilitate process control. Manufacturing process planning has a wide engineering background. Scallan (2003) clarifies that the actual activities in manufacturing process planning depends on the type of manufacturing system as well as the nature of the products of manufacture

Papke-Shields *et al*. (2006) divide the approaches to manufacturing process planning – based on the manufacturing strategy and characteristic of each approach – into three categories that are as follows:

- Rational approach: Rationality of planning based on mechanical *planning* school that is controlled in structure
- Adaptive approach: Adaptive characteristic is associated with *learning* school through participation
- Rational-adaptive approach: This approach is more effective than rational and adaptive approaches for the reason that it supports the development of effective planning process

The definitions of the key elements of rational and adaptive approaches are shown in Table 2-1.

Table 2-1. Different approaches to process planning (Papke-Shields *et al*., 2006)

Construct		**Domain**
Rational characteristics	Flow	Locus of authority for strategic planning
	Formality	Extent to which the planning process is structured, through written procedures, schedules and other documents, and the extent of documentation resulting from the planning process
	Comprehensiveness	Extent to which all possible strategic alternatives are identified and considered
	Focus	Extent to which control or efficiency, usually seen as a tight link with budgets, rather than creativity is emphasised
	Horizon	Length of time considered in strategic planning
Adaptive characteristics	Intensity	Magnitude of resources committed to planning as evidenced by frequency and richness of meetings
	Participants	Variety of individuals involved in strategic planning

In the manufacturing environments, process planning, is used to determine detailed procedures by which work-pieces (parts) are converted from the raw material form to the desired form (Baykasoglu and Özbakır, 2009). Preliminary process planning is a process of early manufacturability assessment on a preliminary design. It supports the optimization of product form, material selection, and resource selection to reduce the manufacturing cost and

time. This activity can be further decomposed into three sub activities: select primary manufacturing processes, select manufacturing resources, and initially estimate manufacturing cost and time (Feng and Song, 2003). The relationship between these activities is illustrated in Figure 2-4.

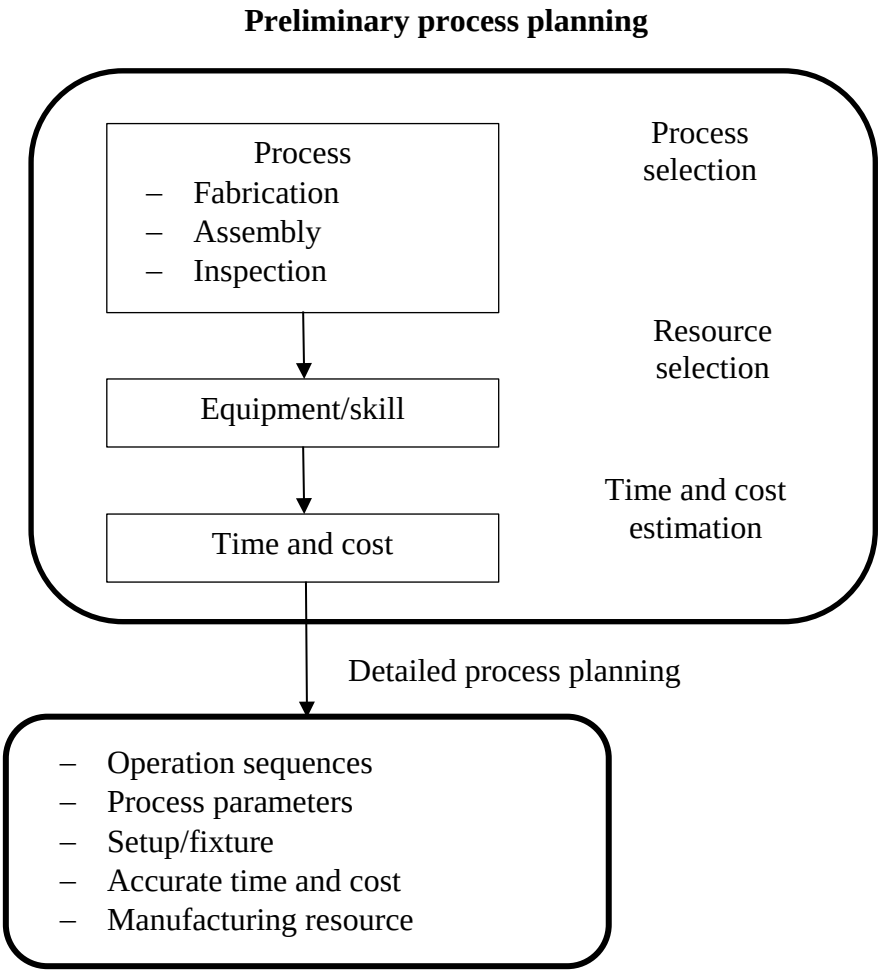

Figure 2-4. Preliminary process planning (Feng and Song, 2003)

The above discourse shows that process improvement can occur if process planning takes into account all the activities involved in the process planning. Improving efficiency in the activities will lead to improved efficiency in the overall manufacturing productivity.

2.3.3. Production scheduling function in the manufacturing system context

The traditional manufacturing develops process planning based on the assumption that the manufacturing resources are available continuously and are unlimited, on the shop floor. Mouzon *et al.* (2007) emphasise that the shop floor with limited resources that are sometimes unavailable fails this traditional perspective, therefore, production scheduling is essential.

Moreover, with optimum production scheduling all the resources on the shop floor will be employed efficiently which can lead to reducing energy consumption. The close relationship between process planning and production scheduling clarifies that integration of these two segregated functions can facilitate more flexible and energy-efficient production (Aghelinejad *et al*., 2017, Gong *et al*., 2017; Zhang *et al*., 2016)

Blazewicz *et al.* (2007) emphasise that production scheduling is as needed on planning level as on the control level. They clarify that different aspects of issues related to production scheduling are as follows:

- Offline-planning (Predictive production scheduling). Offline-planning serves to provide guidance in achieving global coherence in the process of local decision-making
- Online-control (reactive production scheduling). Online-control is concerned with revising predictive schedule when unexpected events force changes

They explain that issues related to production scheduling, where data from the actual manufacturing process are used, can be modelled on the basis of distributed planning and control loops. Offline-planning generates the requirements for online-control and online control creates feedback to offline-planning.

2.3.4. IPPS approaches applied as part of MS initiatives

Approaches to the integration of process planning and scheduling that are described in this section of the thesis.

Non-linear approach to IPPS

Benjaafar and Ramakrishnan (1996) remark that in the non-linear approach (NLA) to IPPS, multiple process plans – that facilitates product flexibility – for parts are created before each part enters the shop floor that are as follows:

- Operation flexibility: Considering operation flexibility that creates the possibility of performing an operation on more than one specific machine
- Sequencing flexibility: Sequencing flexibility allows the possibility of interchanging the sequence that leads required manufacturing operations

– Processing flexibility: Processing flexibility facilitates the possibility of following alternative operations or sequence of operations for producing a manufacturing feature

In addition to product flexibility, the process flexibility can be grouped in a hierarchy as shown in Figure 2-5.

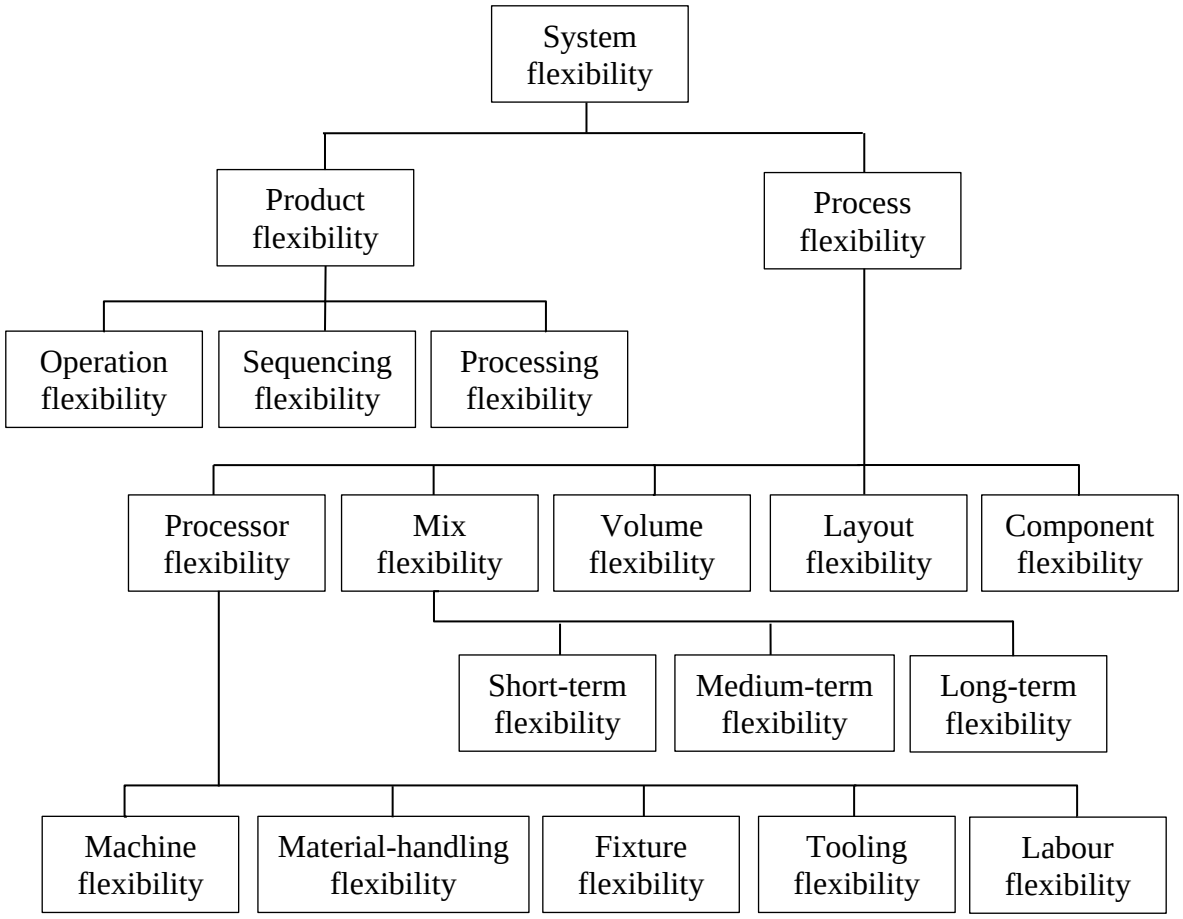

Figure 2-5. Flexibility hierarchy (Benjaafar and Ramakrishnan, 1996)

Non-linear approach to IPPS makes all possible alternative process plans for each part before it enters the shop floor. NLPP is based on static shop floor situation. All possible process plans are ranked based on some criteria and stored in a data base. Production scheduling selects one of those plans; if the first plan is not suitable the second one is selected and so on (Tonshoff *et al.*, 1989). The channels for information flow in this approach are shown in Figure 2-6.

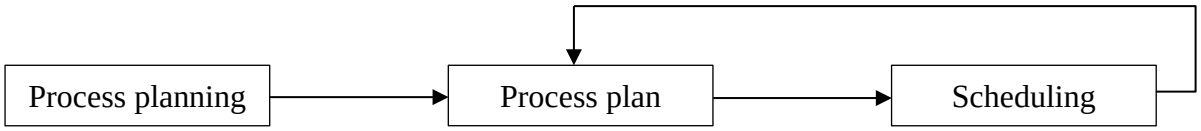

Figure 2-6. Non-Linear approach to IPPS (Zhang and Merchant, 1993)

Closed loop approach to IPPS

Phanden *et al*. (2011) clarify that in the closed loop approach (CLA) to the integration of process planning and scheduling, a dynamic feedback from production scheduling and available resources support the development of process plans. They explain that CLA to IPPS addresses some of the limitations of NLPP through generating process plans by means of dynamic feedback from production scheduling. In this approach production scheduling leads the process planning through identifying available machines for the coming job, based on this information suitable process plan is generated. Kempenaers *et al*. (1996) and Zhang and Merchant (1993) remark that real-time information is critical in closed loop approach to IPPS. The channels of information flow in this approach is illustrated in

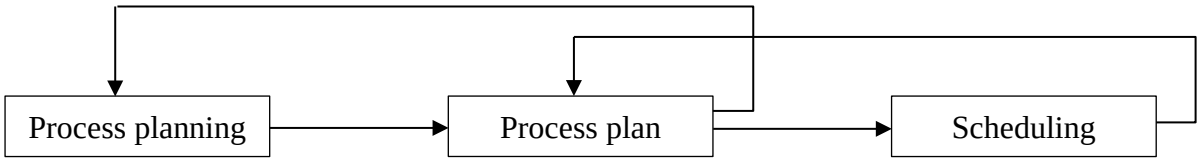

Figure 2-7. Closed loop approach to IPPS (Zhang and Merchant, 1993)

Distributed approach to IPPS

Distributed approach (DA) to IPPS performs process planning and production scheduling simultaneously. There are two phases in this approach. The first phase is pre-planning which analyses features and their interrelationships, and determines corresponding manufacturing processes. In the second phase, required job operations are matched with operation capabilities of the available manufacturing resources to reach final process plans. The integration occurs at the point when resources are available and the job is required. Therefore, this approach facilitates dynamic process planning and production scheduling constrained by real-time events (Phanden *et al*., 2011). The relationship between the key stages of DA approach to IPPS is illustrated in Figure 2-8.

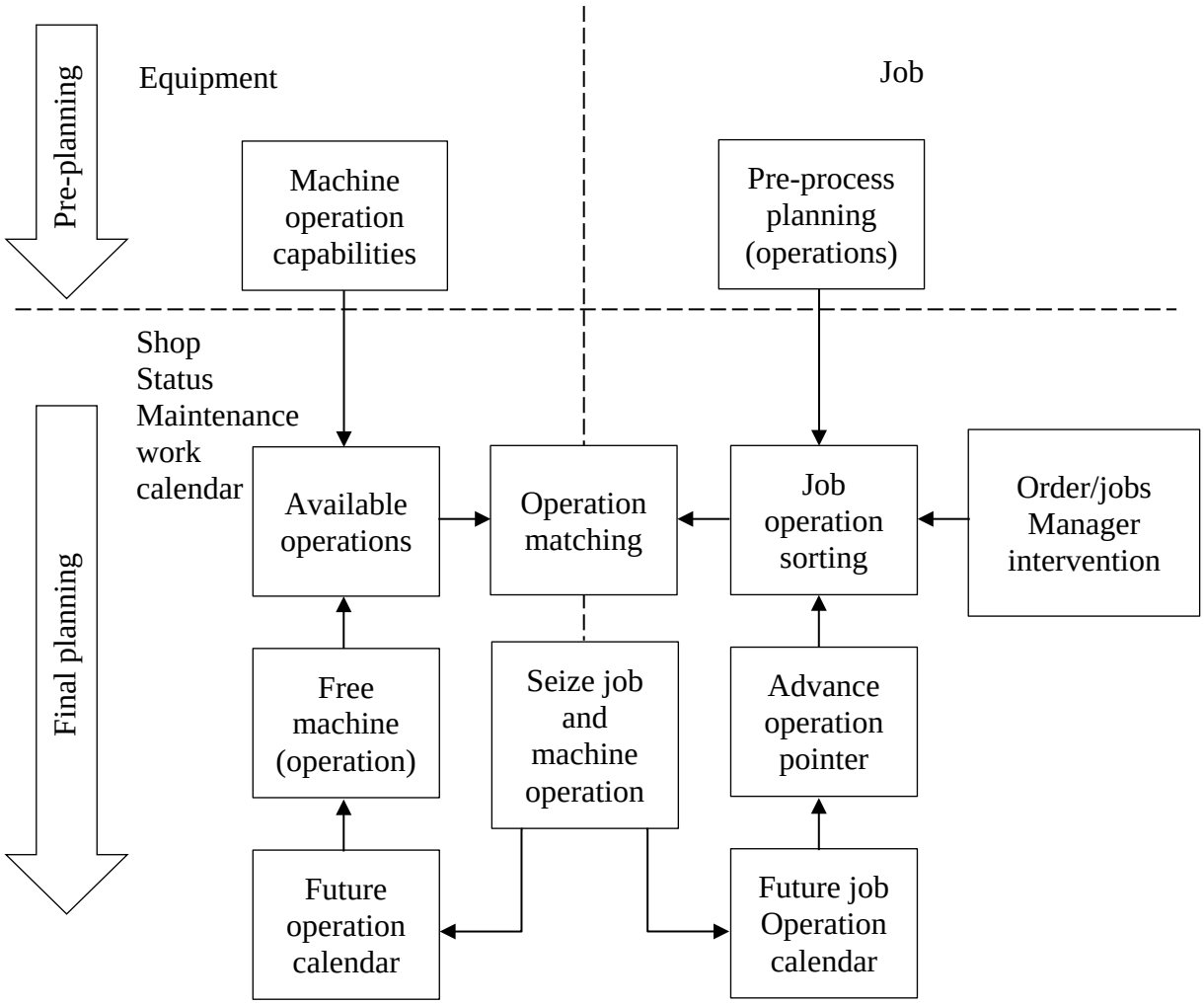

Figure 2-8. Distributed approach to IPPS (Zhang and Merchant, 1993)

A summary of the integration approaches presented in this section of the thesis and their features is included in Table 2-1.

Table 2-2. Features of existing approaches to IPPS (Phanden *et al*., 2011)

Integration approaches	**Features**
NLA	1. Process plans contain alternative routing, which offer high degree of flexibility to production scheduling 2. It contains possibilities of improving off line production scheduling performance and can be quickly react to disturbances on the shop floor 3. It can be implemented in a company that has process planning and production scheduling departments 4. It has one-way of information flow i.e. from process planning to production planning. Therefore, it may be impossible to achieve full optimal results in integrating two functions 5. Some of the process plans created are not feasible according to real time shop status 6. Considering all possible process alternatives for resource allocation may enormously increases complexity of process plan representation
CLA	1. Each generated process plan is feasible and based on current shop floor conditions 2. It enhances real time, intuition and manipulability of process planning system 3. The real-time status of manufacturing system is essential for it 4. It requires high-capacity software and hardware 5. The process planning and production scheduling departments of a company may have to dismantle and reorganise to take the full advantage 6. The adaptation of a step-by-step local view limits the solution space for subsequent operations
DA	1. It completely integrates process planning and scheduling functions and provides the reasonable schedules without generating superfluous process plans 2. It performs process planning and production scheduling in parallel 3. The activities within each phase take place in different time periods 4. The interaction between process planning and production scheduling starts from a more global level and ends at a more detailed level 5. It requires high-capacity software and hardware 6. Process planning and production scheduling departments of a company have to be dismantled and reorganised 7. It has limited scope within some specific CAPP function such as process and machine selection as detailed process planning tasks are shifted down to manufacturing stages for enhancing flexibility 8. It is truly integrated approach with whole solution space available but, due to vast solution space, finding a feasible solution in a reasonable amount of time is difficult

2.3.5. Limitations of existing approaches to IPPS in the MS field

The description of NLA, included in section 2.3.4, affirms that its assumption is based on foreseeing the problem prior to the start of manufacturing and address it where there is possibility of solving that problem. Therefore, as Zhang and Merchant (1993) clarify, the non-linear approach to IPPS is based on static shop floor situation. They explain that the order's batch size, expected manufactured date, capacity of shop floor and optimisation condition for production scheduling – for example, through lead time – are the key factors that lead the decision-making process. Kempenaers *et al*. (1996) highlight that the one-way information flow (see Figure 2-6) in this approach hinders the effectiveness of integrating process planning and scheduling functions. Consequently, NLA is not an optimal approach to IPPS.

Closed loop approach to IPPS addresses, to a certain extent, some of the limitations of non-linear approach to IPPS, however there are number of challenges associated with CLA that are as follows:

- CLA to IPPS demands dismantling and reorganising process planning and scheduling functions which is not feasible for many of the manufacturing companies (Iwata and Fukuda, 1989)
- CLA to IPPS requires tailored software and high-capacity hardware (Zhang and Merchant, 1993)
- In this approach, the solution space for subsequent operations is confined for the preseason that CLA to IPPS requires step-by-step local assessment (Gaalman *et al*., 1999)
- The complexity of manufacturing processes does not support the demand for feeding real-time information into the closed loop approach to IPPS (Joo *et al*., 2001)

Distributed approach to IPPS, in contrast with non-linear and closed loops approaches, facilitates the integration of technical and capacity-related planning tasks into a dynamic fabrication planning system (Larsen and Alting, 1992). However, there are number of problems related to DA to IPPS that are as follows:

- DA to IPPS demands high capacity and significant capability from hardware and software (Phanden *et al*., 2011)

- DA to IPPS does not cover detailed process planning because the boundary of this approach is influenced by specific computer-aided process planning (CAPP) (Joo *et al*., 2001)
- The implementation of DA, similar to CLA to IPPS, demands dismantling and reorganising process planning and production scheduling functions (Haddadzade *et al*., 2009)

2.3.6. Evaluating success of IPPS techniques in MS initiatives

Phanden *et al*. (2011) emphasise that factors such as decreasing lead time, competitive cost, larger part variety and exacting standards of quality have inevitable impact on manufacturing productivity. However, the traditional manufacturing environment – where process planning and production scheduling are carried out in two distinct phases – does not address these factors efficiently. The challenges associated with traditional manufacturing environment can be described in four categories that are as follows:

- Fixed process plans that restrict the schedule to only one machine per operation (Chen *et al*., 2009)
- Unpredictability of the shop floor – for example, lack of required resources (Zhang *et al*., 2016)
- Time delay between process planning phase and production scheduling phase (Baykasolu and Özbakir, 2009)
- Although real manufacturing environment involves more than one optimisation criterion, both process planning and production scheduling focus on single criterion optimisation to determine optimal solution (Augusto *et al*., 2012)

One of the approaches to the implementation of the IPPS is to break up and reorganise the process planning and production scheduling department in an organisation (Phanden *et al*., 2013). However, the success of this approach has been very limited, in particular, because of existing structure of these two departments (Tan and Khoshnevis, 2000). Information systems, to some extent, addresses the limitations of this approach to facilitating information flow between the departments without breaking them up or reorganising them. However, Stein (2003) emphasises that the issues related to computer-based approaches to connecting internal functions of a manufacturing firm are as follows:

- Making any significant change has become very challenging for the reason that the accepted technology had become so ingrained in industry, software companies, and consulting organisations as well as at the university level
- Creating improvements in technology has been prevented due to the significant investment to create the existing software. Therefore, acceptance of new techniques such as just-in-time manufacturing and implementing new methodologies had been, noticeably, encountering significant challenges
- Complete lack of knowledge of the physical laws that govern the manufacturing environment

These issues organise part of the context of this research and will therefore be addressed during the design, implementation and validation of a new approach to IPPS in manufacturing industry.

2.4. Areas that have addressed the integration of process planning and scheduling

2.4.1. Information systems

Boucher and Yalçin (2006) explain that the standard software solutions employed in industrial information systems clarify the need for a hierarchy of decisions in manufacturing that covers all the planning related to manufacturing process. This hierarchy of decisions is illustrated in Figure 2-9.

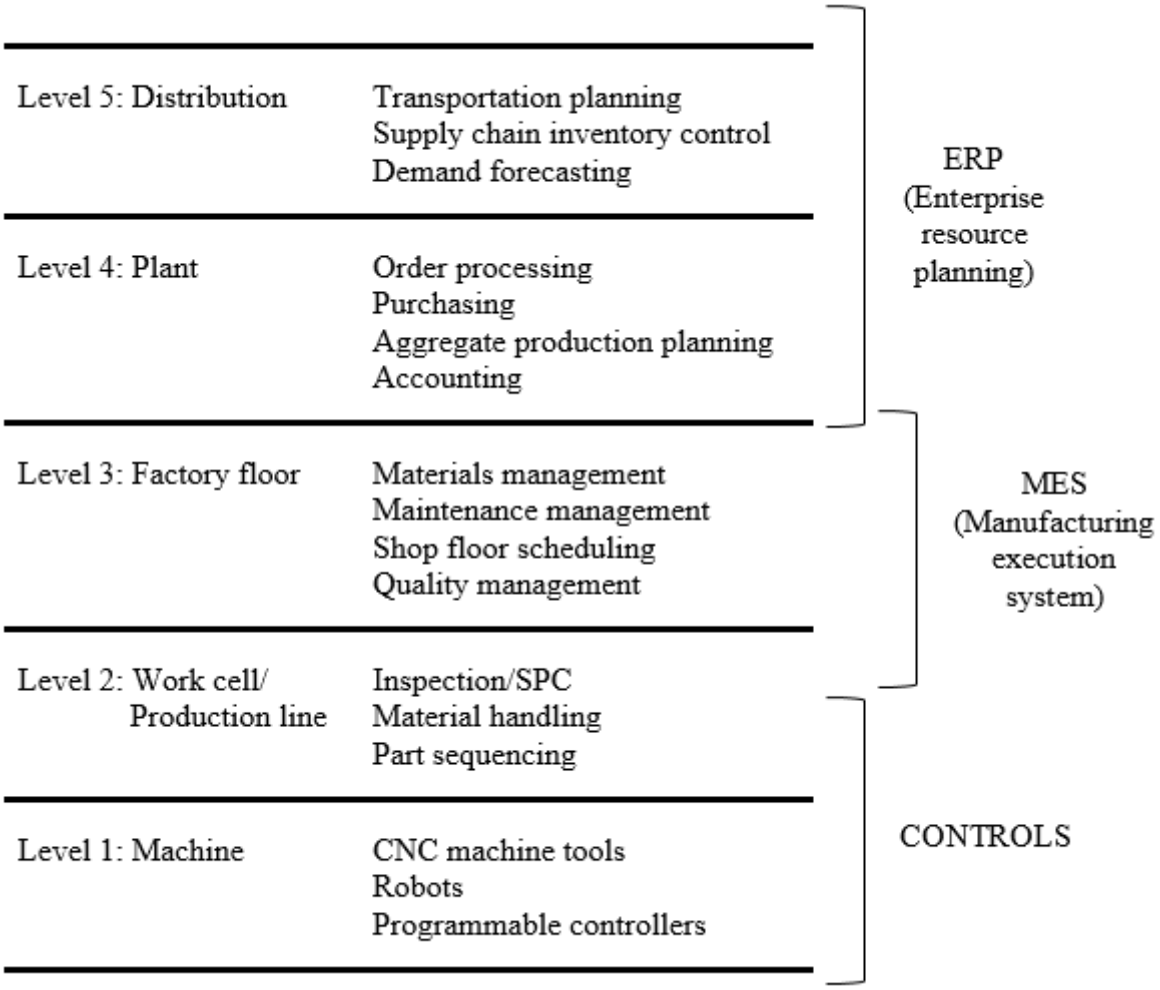

Figure 2-9. Decision hierarchy of industrial information system (Boucher and Yalçin, 2006)

The IPPS problems in the field of information systems

Kim *et al.* (2014) remark that, for many firms, the investment on technologies to increase the effectiveness of the firms' operation process and information system has been facing the complexity related to linking the support from these technologies to improving IKT across different functions or departments in order to support problem-solving efficiency. Boucher

and Yalçin (2006) inform that IPPS approaches in the field of information systems – for example, material requirements planning (MRP) and enterprise resource planning (ERP) – are generally thought of as "planning" systems because they are responsible for supporting the planning of production, but they are not very well integrated into the performance of production.

IPPS approaches used in the field of information systems

Boucher and Yalçin (2006) clarify that development of planning systems such as material requirements planning (MRP) – combines database management systems with application software in order to manage inventory levels and plan production schedules – has significant contribution to supporting integration of process planning and scheduling. Moreover, the continuous improvement of information systems has been significant. For example, capacity planning is included in extended version of MRP – MRP II which was built on the basic MRP model. When MRP provides a schedule of manufacturing activities required to meet a master plan, MRP II takes over and balances the available manufacturing resources, such as workers and machines, to the required production activity. A sample of MRP/MRP II design is illustrated in Figure 2-10.

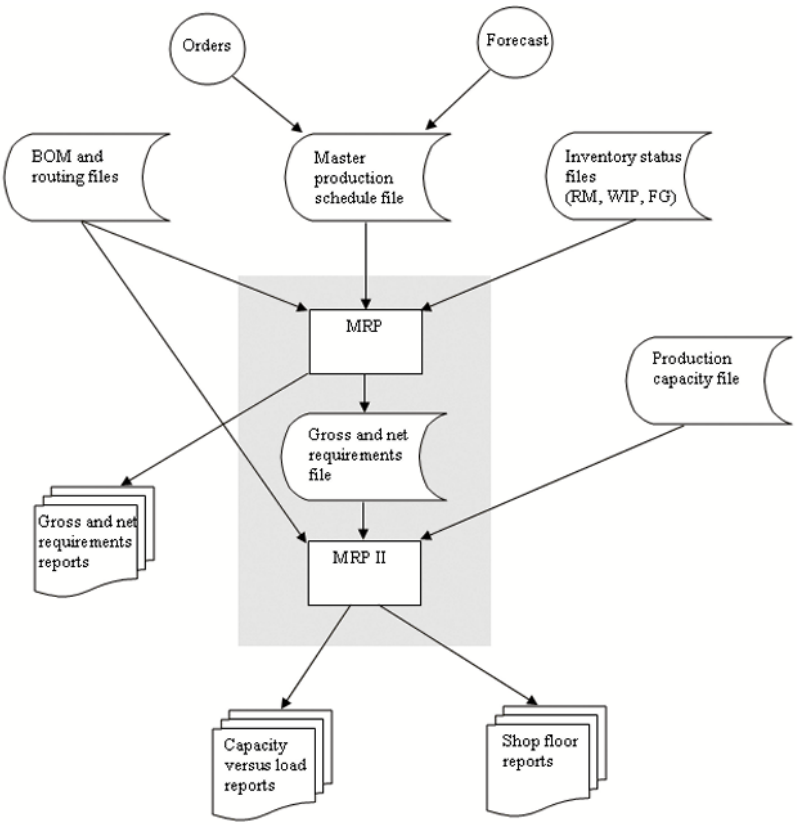

Figure 2-10. Typical structure of MRP planning system (Boucher and Yalçin, 2006)

In order to add more functionality to MRP system, this system has been expanded within enterprise resource planning (EPR). Some of the functions that ERP system supports are as follows:

- Quality management
- Sales and distributions
- Human resource management
- Project management

In the field of manufacturing system, in order to support IPPS, ERP was extended beyond the manufacturing firm which was followed by supporting more functions such as logistics supply chain management and intercompany communications. However, the contribution of the development in these systems to manufacturing productivity has been insufficient.

Evaluation of the success of IPPS approaches used in the field of information systems

The limited available software solutions on the shop floor has led to the development of the manufacturing execution system (MES). Boucher and Yalçin (2006) explain that the MES functions include advantages over other systems, such as MRP and EPR, that are as follows:

- Dispatching and monitoring production: Controlling the release of work orders to the shop floor and tracking work-in-process inventory
- Detailed production scheduling associated with specific production units in order to meet specific performance criteria
- Data collection from factory floor operation to provide a history of factory events
- Quality data analysis: providing real-time analysis of measurements collected from manufacturing, notifying production personnel of out-of-tolerance conditions, and sometimes analysing data to recommend corrective action
- Product history recording: Providing a history of product manufacture for genealogy or regulatory purposes and tracking the specific lot of materials and specific machines used

Consequently, the MES provides a functionality closer to the performance of production in comparison with MRP system. The MES also provides actual results that can be fed back to planning systems for updating plans over the next planning horizon. Importantly,

manufacturing execution system provides functions that are just above the level of actual real-time control of machines and processes.

2.4.2. Operations management

The IPPS problems in the field of operations management

One of the most critical aspects in operations management is making manufacturing firm sustainable and competitive. In this aspect, productivity is a vital issue. Measuring the manufacturing productivity is a very complex task as few mutually exclusive components such as labour productivity, process efficiency, degree of technology used, targeted quality of the products is associated with manufacturing system. Additionally, and more specifically, initial setup and breakdown time of machineries, adjustment time for restarting the production, idling of machineries caused due to lack of proper production planning and production scheduling, number of defective products and its rework are actively involved with measuring process of productivity.

IPPS approaches used in operations management

One of the greatest challenges to the creation of an effective framework that delineates the various operational activities of a manufacturing company is the determination of a distinction between logistics and operations management. As expressed in the previous section, early logistics research explored efficient warehousing, materials and inventory management, and inbound and outbound transportation. Yet management of these activities shares a distinct similarity with operations management activities. In fact, many of the issues commonly covered in logistics research, teaching, and practice (for example, facility location, order management, and procurement) are also considered core elements of operations management. It is not surprising, therefore, to discover a general confusion regarding where the domain of logistics ends and the domain of operations management begins.

Internal processes that fall within the purview of operations management include place/location and time/storage transformation (or logistics), possession/exchange transformation (or marketing), and physical transformation (or production/service) (Chase *et al*., 2006). According to this definition, the distinguishing aspect of functional management, as compared to operations management, is that the scope and domain of functions are narrowly defined as focusing on: planning, controlling, and executing existing management activities that fall within the sphere of each individual functional area. Functional

management focuses on existing activities and the most efficient control and execution of such activities, operations management is more focused on enhanced firm effectiveness and efficiency through process improvement, planning, and control. Hence, functional management is about executing processes, while operations management is more directly concerned with improvement of processes particularly as related to coordination of the cross-functional interfaces within a firm. When the scope of decision-making for each area of management crosses functional boundaries, it may then be considered to be within the managerial realm of operations management.

In regards to addressing IPPS in the field of operations management, even before the term IPPS has gained its meaning, the possible pattern for information flow (feedback) has been considered by authors as illustrated in Figure 2-11.

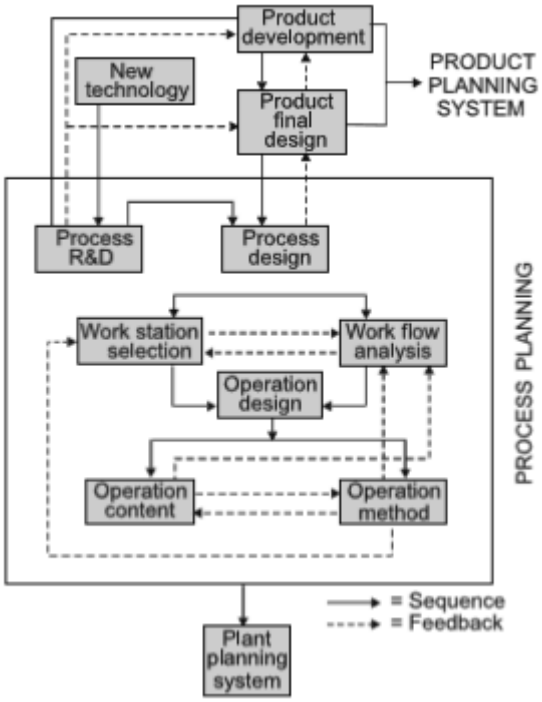

Figure 2-11. The process planning task (From Timma and Pohlen, 1970 in Kumar and Suresh, 2009)

Evaluation of the success of IPPS approaches used in the field of operations management

Operations management can be characterized as decision-making and problem solving that involves application of operations research and management science quantitative methods to support the efficient and effective allocation of scarce resources associated with a

manufacturing company's operations (Sahin and Robinson Jr, 2005).The earliest research in managerial systems dealt with production, and indeed, the managerial system was thought of as the production operations system by classical economists (Buffa, 1982). The definition of operations management as expressed by the introductory textbooks, therefore, was virtually the entire field of industrial management, including chapters on personnel, finance, marketing, distribution, organisation, production, and general management. As business thought evolved, the individual functional fields of management and the field of general management spun off and "operations" was left with topics related to production system techniques such as time and motion study, plant layout, Gantt's production control boards, *economic order quantity* inventory modelling, and descriptions of how production systems work (Buffa, 1982; Levitt, 1972). Over time, operations management expanded to include the study of service operations systems as a natural broadening of production management (Levitt, 1972). Advances in operations research and management science provided the scientific methodology that allowed operations researchers to develop a better understanding of the basic mechanics of production and service subsystems related to inventories, scheduling, aggregate planning, quality control, and capacity planning (Buffa, 1982; Levitt, 1972).

2.4.3. Lean manufacturing

Feld (2001) clarifies that for lean manufacturing, there are five primary elements, that include various aspects which are listed in Table 2-3, required to develop and support an efficient lean manufacturing programme. These primary elements are as follows:

- Manufacturing flow. Physical changes and design standards that are deployed as part of the cess are addressed through manufacturing flow aspect of lean manufacturing
- Organisation. Identification of people's roles or functions, training in new ways of working and communication are the focus of organisation aspect of lean manufacturing
- Process control. Monitoring, controlling, stabilising and following patterns to improve the process are directed within this aspect of lean manufacturing
- Metrics. This aspect of the lean manufacturing revolves around addressing visible, result-based performance measure, team rewards of recognition and targeted improvements

- Logistics. Operating rules and mechanisms for planning and controlling the material flow are defined through this aspect of lean manufacturing

Table 2-3. Primary elements of lean manufacturing (Feld, 2001)

Primary elements of lean manufacturing	**Aspects**
Manufacturing flow	9. Product/quantity assessment (product group) 10. Process mapping 11. Routing analysis (process, work, content and volume) 12. Takt time (The word takt comes from the German word for rhythm or beat). The equation for measuring takt time is as follows: $\text{Takt time} = \frac{\text{Total time available per day}}{\text{Designed daily production rate}}$ 13. Workload balancing 14. Kanban sizing (Kanban is a Japanese word which means card or sign and is a pull system in just-in-time production) 15. Cell layout 16. Standard work 17. One-piece flow
Organisation	1. Product-focused multi-disciplined team 2. Lean manager development 3. Touch labour cross-training skill matrix 4. Training (lean awareness, cell control, metrics, statistical process control (SPC) and continuous improvement) 5. Communication plan 6. Roles and responsibility
Process and control	1. Total productive maintenance 2. Poka-yoke (fail safe) 3. Single-minute exchange of dies (SMED) 4. Graphical work instructions 5. Visual control 6. Continuous improvement 7. Line stop 8. SPC 9. 5S housekeeping (to throw out unnecessary items and identify required items)
Metrics	1. On-time delivery 2. Process lead-time 3. Total cost 4. Quality yield 5. Inventory (turns) 6. Space utilisation 7. Travel distance 8. Productivity
Logistics	1. Forward plan 2. Mix-model manufacturing 3. Level loading 4. Workable work 5. Kanban pull signal 6. A, B, C parts handling 7. Service cell agreements 8. Customer/supplier alignment 9. Operational rules

The IPPS problems in the field of lean manufacturing

Rahman *et al.* (2013) emphasise that lean manufacturing practices improves operational performance. Panizzolo *et al*. (2012) inform that lean manufacturing has significant value for manufacturing companies in developing countries for the reason that reducing energy consumption is not only valuable in terms of manufacturing productivity but it is a necessity. Feld (2001) remarks that the success of approaches to implementation of lean manufacturing (e.g. event-based approach) relies on the ability of manufacturing companies in regards to sustaining change. Therefore, there is a significant relationship between level of performance change of the manufacturing companies and the success of lean manufacturing. The factors that have negative impact on implementation of lean manufacturing are as follows:

- The manufacturing company has not prepared its employees and function prior to implementing lean manufacturing. This can be result of factors such as follows:
  - Unavailability of required data for beginning the analysis during the early phases of the implementation
  - Lack of sufficient awareness of employees in terms of management's expectation
- Unfamiliarity of employees with the aim and objectives of lean manufacturing. unawareness of the significance of lean manufacturing programme for the manufacturing company. Lack of communication between the manufacturing company and its employees that could be followed by uncertainty about how the lean manufacturing programme fits into existing business initiatives
- The challenges associated with follow-up on "to do" activities and coordination of multiple assignments after the implementation of lean manufacturing programme
- Key resources within the business could become overwhelmed with work, especially maintenance and information systems

IPPS approaches used in the field of lean manufacturing

Rahman *et al.* (2013) one of the approaches to lean manufacturing is Kanban (included in the aspects of manufacturing flow in Table 2-3) which is a system that assists suppliers of material based on minimum level of inventories in the production line. However, issues related to lack of interconnectedness of process planning and production scheduling functions

alters the inventories number that should be equal with the production numbers which results in ineffectiveness of Kanban approach for some manufacturing companies.

Feld (2001) explains that, in terms of functionality similar to production scheduling, the process planning requires that specific work rules to be utilised during the operation process. Moreover, scheduling of work – for example in the process of prioritising work-flow on a first-in/first-out – requires physical handling of material and, therefore, it is not independent function. Furthermore, not every product has a demand pattern conductive to rate-based scheduling. Mix-model manufacturing – highly flexible workforce with limited variation between work content times for each operation – can address this challenge through supporting production of any mix of any product on any day and providing the ultimate responsiveness and utilisation of floor space. Employing this approach to production scheduling facilitates most effective use of space, equipment, people, time, material, etc. However, although mix-model manufacturing is more effective compared to segregated production, it is more complex and many manufacturing companies fail to implement it effectively.

Evaluation of the success of IPPS approaches used in the field of lean manufacturing

Feld (2001) clarify that in order to succeed in the implementation of lean manufacturing programmes, the manufacturing companies need to successfully achieve improved performance and, more importantly, sustain it. He explains that the factors which facilitate this achievement are as follow:

- Leadership. Leadership has significant influence on the success of lean manufacturing. Skilled leaders support the employees to learn or clearly understand their roles within the lean manufacturing programme and create an environment that constantly motivates the employees to eagerly collaborate throughout the implementation of this new approach
- Direction. It is important to clearly verbalise the overall plan or vision that includes the feasibility of achieving the mission lean manufacturing programme. Another essential step is to communicate the knowledge about the process of the implementation of the programme that identifies the technique required along the process progress

- Common goal/objective. Creating credible goal/objective resolution assists the team involved in the implementation of lean manufacturing programme in terms of comparing current performance against the identified deliverables which facilitates tracking performance and achieving those deliverables
- Support. It is essential to familiarise the team involved in the programme with the required tools and techniques. It is important to facilitate constant interaction with team members to encourage them and help them to progress when they encounter any difficult step during the implementation process of lean manufacturing programme.

2.4.4. Supply chain management

As opposed to a focus on the activities that constitute supply chain management, other authors have focused on management processes. Davenport (2014) defines processes as a structured and measured set of activities designed to produce specific output for a particular customer or market. SCM is the process of managing relationships, information, and materials flow across enterprise borders to deliver enhanced customer service and economic value through synchronized management of the flow of physical goods and associated information from sourcing to consumption. In other words, it is a process where there is a specific ordering of work activities across time and place, with a beginning and an end, clearly identified inputs and outputs, and a structure for action.

The IPPS problems in supply chain management

The supply chain improvements described indicate that supply chain management has the potential to improve a firm's competitiveness. Supply chain capability is as important to a company's overall strategy as overall product strategy. Supply chain management encourages management of processes across departments. By linking supply chain objectives to company strategy, decisions can be made between competing demands on the supply chain. Improvements in performance are driven by externally-based targets rather than by internal department objectives.

Managing the supply chain means managing across traditional functional areas in the company and managing interactions external to the company with both suppliers and customers. This cross-boundary nature of management supports incorporating supply chain goals and capabilities in the strategic plan of the company. This focus on integration can then lead to using the supply chain to obtain a sustainable competitive advantage over competitors.

The impact of managing overall product demand and the supply of product will impact the profitability of the company. The supply chain strategy can be viewed as the pattern of decisions related to sourcing product, capacity planning, conversion of finished product, deployment of finished product, demand management and communication, and delivery. Linking supply chain strategy to the business strategy involves defining the key business processes involved in producing a company's product or service.

IPPS approaches used in supply chain management

Stevens (1989) explains that realising competitive advantage from organisational alignment and SCM in relation to materials supply is a form of backward integration; at first, it involves the focal enterprise forging alliances of distribution and manufacturing activities to deliver improvements for the final customer (internal integration). He remarks that in the process, the manufacturing company obeys demands from distributors; purchasing is in turn re-structured and managed to achieve improved customer value for manufacturing; thereafter, the process addresses the suppliers to the organisation (external integration) typically involving supplier rationalisation and the introduction of supplier evaluation systems. He clarifies that the evolutionary process develops through: the baseline organisation; the functionally integrated company; the internally integrated company; and finally, the externally integrated company.

Evaluation of the success of IPPS approaches used in supply chain management

A company must develop objectives for the management of the supply chain based on corporate objectives. From these higher-level objectives, a set of detailed objectives can be developed for each process within the supply chain. This cascading method serves to integrate the supply chain processes with the overall enterprise direction and provides measures for monitoring and execution. Supply chain management can be utilized to be a point of differentiation for a company. Excellence on a certain dimension in product position can provide a competitive marketing opportunity, but shortfalls in providing this dimension by the supply chain can eliminate this advantage. For a company to be competitive, it is not enough just to vary marketing programs. They must define a working relationship with customers and put themselves in a position to deliver customer value. All components of the supply chain must have the capability to meet strategic objectives.

Companies must evaluate the effectiveness of the supply chain strategy using a new set of measures. Typical rewards aimed at improving performance of functions or departments must

be revised to strive to improve supply chain performance overall. By tying the supply chain strategy to the overall company strategy, the objectives become process objectives rather than functional objectives.

For example, traditionally, one of purchasing's measurements is material cost or material variance. Buying product at a lower cost is one way to improve that measure. Purchasing a carton at a lower cost from a new vendor might lower the cost of the carton. However, the new carton may not run as efficiently through the production process as the one from the original supplier. Purchasing's measure of material variance is favourable, but the manufacturing facility is recognizing added costs in downtime, maintenance, etc.

Measurements must be designed to look across the supply chain and become process objectives. Included in that process is the internal structure of the supply chain which often is causing as much confusion/cost as external portions of the chain.

2.4.5. Collaborative leadership

The IPPS problems in collaborative leadership

Leading intra-organisational information and knowledge transfer involves setting up an environment in which members of different functions in a manufacturing company meet and collaboratively find solution to the problems that they could not find individually. Lack of effective and efficient facilitation of IKT in such environment could result in significant exchange of data rather than problem-centred information and knowledge. Moreover, Ernst and Chrobot-Mason (2011) emphasises that diversified functions of manufacturing company might have different understandings of a given problem and poor leadership of the IKT would lead to creating a more complex problem rather than developing a solution.

IPPS approaches used in collaborative leadership

Schwarz (2000) remarks that facilitating participation environment is one of the several fundamental elements of effective information and knowledge transfer and without collaborative leader, participation might not result in achieving the communication purpose. Therefore, creating participation environment is a requirement for effective collaboration rather than an end.

In collaborative information and knowledge transfer, collaborative leader is the essential requirement for effectiveness and success of the collaboration. Schwarz (2014) informs that

mutual learning is the core element of collaborative leader approach. He emphasises that the mutual learning reduces unproductive conflicts and increases the effectiveness of collaboration. In the process of implementing IPPS, it is essential to prepare and lead the involved functions through the change. Scharmer (2008) explains that it is important for the collaborative leaders to address the structural habits of attention and interaction that is the result of incorrect habits of listening. He categorises the different types of listening into four types that are as follows:

- Downloading. This type of listening includes reconfirming usual conclusions
- Factual. Individuals pay total attention to other individual's speech without drawing expected conclusion. This type is object-focused listening during which individuals become aware of the differences between their previous knowing and understanding and the current transferred knowledge.
- Empathic. Individuals create deeper level of listening through engaging in real conversation and form the empathic listening. This type of listening supports better understanding of individual's perspective on the impacts of the matter in hand.
- Generative. This type of listening involves willingness to unlearning and developing new knowing. Generative listening and responding is the most challenging factor for leaders and fundamental in investigating and addressing root causes of problems.

Moreover, the role of collaborative leader consists of three levels of facilitating meetings, focused discussions and interaction. The structure of the meetings, type of discussion and level of interaction depend on the degree of participants' familiarity with collaborative information and knowledge transfer. These three levels are as follows:

1. Level one of facilitating meetings – functions input meeting

The role of the collaborative leader is passive at this level. This allows the individuals from different functions of manufacturing company to engage in introducing the information and knowledge resources that could contribute to IPPS without any interfering decision from the collaborative leader. Therefore, the collaborative leader has the role of 'participant as observer', mainly observes, and ascribes the list of relevant and available information and knowledge resources.

2. Level two of facilitating meetings **–** collaborative leader(s) interaction

The role of the collaborative leader is active at this level and includes individual-focused consisting of storytelling and observation.

The observation method allows the collaborative leader to closely observe the professional activity of concerned functions. It is important that the collaborative leader clarifies the purpose of the observation for the participating functions and avoids any intrusion into the work of functions. In addition, storytelling provides a communication channel between the collaborative leader and functions. It improves the understanding of the collaborative leader about the required problem-centred information and knowledge.

3. Level three of facilitating meetings – functions review and reflect meeting

Individuals from functions of manufacturing company and collaborative leader both have active position throughout this level. It involves collective methods consisting of focussed discussions and brainstorming. Focused discussions supports selecting the individuals from functions with the most relevant problem-centred information and knowledge and brainstorming facilitates overcoming the challenges associated with engaging unavailable individuals or the ones not willing to participate.

Evaluation of success of IPPS approaches used in collaborative leadership

Ansell and Gash (2012) affirm that the fundamental challenges associated with intra-organisational information and knowledge transfer are as follows:

- Creating a team of individuals from different functions of manufacturing company who have problem-centred information and knowledge and are willing to learn from and with each other
- Creating and holding collaborative environment
- Facilitating information and knowledge transfer

First, a team of individuals who have negative or no experience of participation in collaborative IKT with other individuals or functions and not willing to learn from and with each other is one of the challenges associated with complexity of intra-organisational information and knowledge transfer. Therefore, the success of IPPS can depend on creating a team of individuals from the concerned functions who have problem-centred information and knowledge and motivating them to learn from and with each other.

Second, incompatible recognition of the problem-related factors affecting different functions in a manufacturing company results in conflicts of perspectives and ineffective interaction between functions. Consequently, addressing these have significant impact on the success of IPPS.

Third, the purpose of information and knowledge transfer is engaging functions in finding a solution for the problem in their manufacturing company that minimises the company-wide effects of the problem and improves performance of the manufacturing company as one whole rather than a solution that satisfies the functions, individually. Therefore, inspiring the functions to engage in information and knowledge transfer, that their knowledge and ideas are needed to support the outcome of the collaboration and they will benefit from the outcome, contributes to the success of IPPS.

2.5. Summary of lessons learned from the literature

The process of integration of process planning and scheduling has been part of manufacturing system since early 1990s. It conveys the idea that manufacturing companies can improve manufacturing productivity through promoting collaboration between two distinct process planning and production scheduling functions. Development of different approaches to implementation of manufacturing system initiatives in manufacturing companies has been followed by application of a range of approaches to IPPS including technology-based approaches. technology-based approaches assist information and knowledge transfer between different departments of manufacturing companies where flow of information could improve manufacturing productivity. However, the challenges associated with developing reliable software and efficient hardware has been inevitable in existing approaches to IPPS.

Effectiveness of IPPS which can have significant impact on manufacturing productivity, in particular for developing countries with problems related to energy consumption, would not emerge without collaborative environment that addresses the barriers that prevent information and knowledge transfer across process planning and production scheduling functions. Although manufacturing companies have been implementing number of approaches to IPPS, the limitations of IPPS approaches exist that are mostly related to:

- Manufacturing company’s willingness to participate in promoting collaboration between their process planning and production scheduling functions
- Diverse characteristics of process planning and production scheduling functions

- Information and knowledge transfer boundaries that hinder effective knowledge flow across process planning and production scheduling functions

In many cases, the manufacturing companies expect fast result and evaluate the overall impact of manufacturing system initiatives on manufacturing productivity instead of evaluating the success of IPPS processes and its impact on business improvements.

Review of the existing approaches to integration of process planning and scheduling and the limitations of each approach shows that the effectiveness of integration of process planning and scheduling has not been fully achieved. These limitations form part of the context of this research. Therefore, the researcher will address these limitations during development, implementation and validation phases of a new approach to IPPS in manufacturing companies in developing countries.

CHAPTER THREE

3. Research methodology

The study of the relationship between the concept of the integration of process planning and integration and its influence on manufacturing productivity varies in different contexts. This chapter describes the path taken by the researcher to enable him to prove that improving the process of integration of process planning and scheduling can be employed as an approach to maintain effectiveness of the integration of process planning and scheduling followed by manufacturing productivity in developing countries. The purpose of this chapter is to assist the reader to understand this path. Consequently, this chapter includes the discussion of research methodology choices that this research adopted in order to address the research questions which are presented in chapter one of this thesis. This discussion covers 1) research strategy, research design and methods, 2) the strengths and weaknesses of them 3) and the feasibility and competence of the research approach adopted to conduct this study.

3.1. Introduction

Chapter one and chapter two identified that the key element of this research is effectiveness of integration of process planning and scheduling. It became clear that there is essential to adopt the research methodology that can support the assessment of significance of data collection and data analysis methods for the purpose of addressing the research questions.

Improving manufacturing process planning requires good knowledge of the processes involved in manufacturing activities as well as production scheduling techniques. Chapter two clarified that the process planning involves a number of steps that must be integrated for the required outcome. In order to capture all the steps involved, it is important to collect data that meets all such requirement and in a manner that can help contribute to the development of a new approach to integration of process planning and scheduling. Studies on research

methodology suggest that the design of the research serves as the blue print for linking the aims of the objectives of a study to the final outcomes through using the most appropriate methodology to collect and analyse data for the research. Creswell and Plano (2017) suggest that research crucially depends on the appropriate selection and implementation of research methods.

Silverman (2013) groups the structure of data collection and data analysis into three areas that are as follows:

1. The theoretical assumptions that formed the process of data collection and analysis that are reported in this thesis
2. The factors that led the researcher to choose to work with these particular data
3. The impact of the overall strategy adopted, the research design and techniques used by the researcher on the conclusions of the research and the feasibility of generalising from the analysis.

A brief description of these areas in included in this chapter. A detailed description of the processes of data collection and data analysis will be included in chapter five and chapter six. The sequential pattern of addressing these areas in the body of this thesis is illustrated in Figure 3-1.

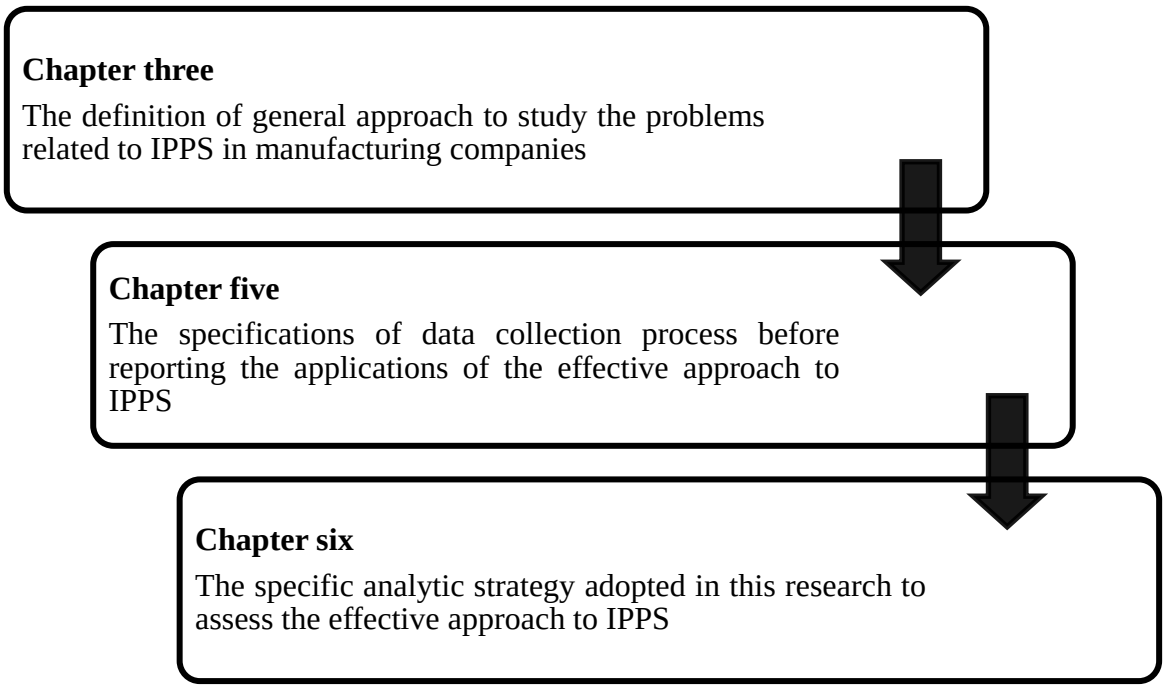

Figure 3-1. Sequential pattern of addressing data collection and analysis

Addressing the research questions

The research questions defined in this thesis suggests the necessity of investigating existing theories relevant to integration of process planning and scheduling in the field of manufacturing system. This research focuses on elements of manufacturing productivity related to process planning and production scheduling functions in manufacturing companies of Nigeria and does not address the financial factors associated with facilitating the integration of process planning and scheduling.

In this thesis, the researcher investigates practical constructs. In addition to traditional view of corporate social responsibility that focuses mainly on organisational level of analysis and does not include individual or groups perspectives (Orlitzky *et al.*, 2011), this research constitute focuses on engaging participants from key manufacturing companies in Nigeria.

Answering the research questions constitute understanding the key dimensions of the research questions. The qualitative method of collecting primary data, discussion to understanding each company's perception, is used in this research in addition to quantitative method, questionnaire to elicit the views of employees and managers within the companies.

Bryman (2016) explains that although discussion involves words more than numbers, it cannot be precisely confirmed that discussion is only communication of words in the qualitative methodology. Moreover, O'Brien (2012) remarks that understanding past events including quantitative and qualitative data has an important influence on understanding current events. Different individual's perception of the past events affects the process using discussion to present comprehension of past events and experiences. Skilful leader of the discussion uses these differences and creates effective discussions around the past events.

3.2. The key concepts that support the conduct of this research

This section presents the descriptions of the terms that supports defining the researcher's theoretical assumptions and identifying the process of data collection and analysis. Silverman (2013) describes these terms in six basic research terms that creates the level of research analysis. The first research term is the author's *mental model* of the research; the second term is *concepts* and it includes the concepts related to addressing IPPS in manufacturing companies; the third term, *theories*, revolves around supporting the study of concepts; the fourth term is *hypotheses* that presents a testable proposition. The fifth term, *methodology*,

describes the general approach to studying research topic. *Research method* is the sixth term that means a specific research technique (e.g. interview, discussion). The specific descriptions of this research terms are as follows:

1. Mental models

The researcher's understanding of the reality surrounding research problem influences investigating the research problem. Such an understanding of reality is referred to in the literature as *models* or *mental models*. Mental models are research paradigms that represent the overall framework for perception of reality of the researcher. Therefore, mental models are instruction to understanding of a particular fact or event and they are self-confirming (Silverman, 2013). Norman (2014) remarks that mental models provide predictive and explanatory ability for understanding the interaction between individuals and environment. Johnson-Laird (1983) explains that cognitive characteristics or 'mental models' represent the analogies that individuals create and manipulate in their minds that develop individuals' perspectives. Therefore, researcher's mental model has a significant influence on developing the research questions, the data collection and analysis.

Silverman (2013) affirms that the fundamental elements of mental models are *ontology* and *epistemology*. He explains that these two elements represent the understanding of the researcher about reality and the concept of knowledge. Bryman and Bell (2015) describe that *ontology* of the research includes the explanation of the meaning and basic elements of understanding of reality for the researcher who conducted a particular study. Therefore, a description of the researcher's mental model assists the clarification of researcher's approach to study manufacturing companies as social entities to clarify the influence of external factors on the individuals' involvement in the process of integration of process planning and scheduling. Bryman and Bell (2015) describe that *epistemology* of the research includes the researcher's understanding of the concept knowledge. Therefore, a description of the researcher's mental model clarifies whether the researcher recognises that qualitative data such as individuals' perceptions could be regarded as acceptable knowledge in the process of addressing the research questions.

2. Concepts

Concepts support the researcher to interpret the ideas that derived from a specific mental model and they are essential in defining a research problem. Concepts, similar to mental models, direct the interpretation of a particular fact or event and they are self-confirming

(Silverman, 2013). Moreover, concepts are the building blocks of theory and represents the points around which research is conducted (Bryman and Bell, 2015).

3. Theories

Theories arrange the grouping of concepts that supports the development of a particular definition or explanation of a fact or event and they provide motivation for research. Theories, similar to models and concepts, are self-confirming and they can never be disapproved but the degree of its significance varies depending on the individuals' perception (Silverman, 2013). Myers (2013) explains that to understand the perceptions and intentions of research participants, the researchers need to involve reliable theories in their research which can never be disproved.

4. Hypotheses

Hypothesis, unlike models, concepts and theories, is not self-confirming and their validity relies on their success or failure in real life (Silverman, 2013). The researcher can evaluate and modify the hypotheses following the finding of the research (Myers 2013)

5. Methodologies

Methodologies or research strategies consist of selection of approaches to data collection and analysis to plan and execute the research. Similar theories, methodology is self-confirming and its degree of value varies between different perspectives (Silverman, 2013). Bryman and Bell (2015) emphasise that a methodology defines a general orientation to the conduct of research.

6. Research methods

Like methodology, *methods* are self-confirming and their value depends on their fit with theories, methodologies and hypotheses. They consist of particular research techniques that can vary from qualitative to quantitative techniques or include both of the techniques (Silverman, 2013). Bryman and Bell (2015) describe research method as a specific technique for collecting data.

The schematic relationship between these six research terms is illustrated in Figure 3-2. The arrow between *findings* and *hypotheses* indicates a feedback mechanism that presents the opportunity to modify hypotheses in the light of findings.

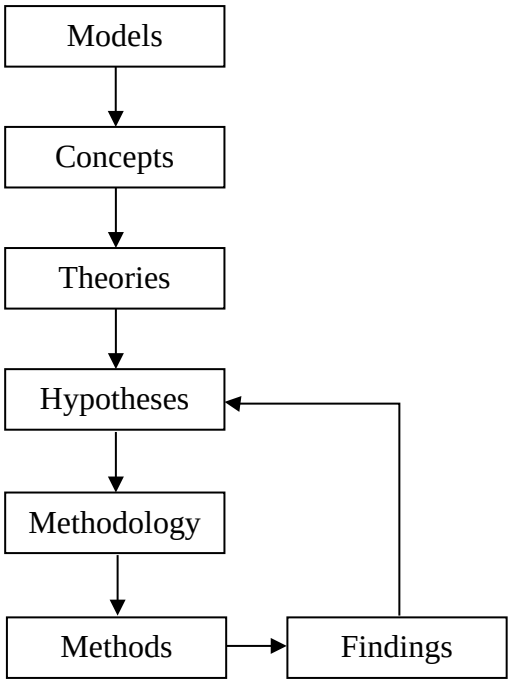

Figure 3-2. The relationship between the six research terms (Silverman 2013)

3.3. Theoretical assumptions

In this research, the theoretical assumptions that are specified by the implications that are as follows:

- The researcher's mental model
- The research ideas in the field of IPPS that contributed to the starting point of the research
- The concepts deriving from the research ideas
- The theories supporting these concepts and contributed to the definition of hypothesis

3.3.1. The research paradigms

Research paradigm consists of the factors that clarify what should be studied, how research should be done and how results should be interpreted (Bryman and Bell, 2015). The primary focus of this research is on the importance and effectiveness of integration of process planning and scheduling within manufacturing companies in developing countries. The researcher value manufacturing industry as entities that are under the influence of manufacturing companies' perceptions of manufacturing productivity and actions. Therefore, it was important to consider the influence of manufacturing companies' perception and ideas on the success or failure of integration of process planning and scheduling. Gergen and

Thatchenkery (2004) emphasise that the theoretical commitment of the researcher supports the research quality. Following this, the researcher considered the studies that address the manufacturing values associated with effectiveness of integration of process planning and scheduling. Moreover, this research value the role of manufacturing values on assisting participation in implementing and maintaining integration of process planning and scheduling with the aim of addressing the effectiveness of the IPPS process.

Review of the various positions on research paradigm or philosophical world views suggest that the world view forms the basis for the methodology adopted for a research and at the same time affects the methods used for the collection and analysis of data (Creswell, 2013). Traditionally, there are two main paradigms or world views for conducting research and these are: positivism and interpretivism. Recently, combinations of these traditional paradigms have also resulted in new paradigms which is pragmatism. These paradigms and their propositions for research are as follows:

- Positivism. Based on the stances of ontology, epistemology and axiology, the positivism paradigm, according to, assumes that a phenomenon obeys natural laws and can be subjected to quantitative logic (Fellows and Liu, 2008). Positivism also assumes that reality can be observed, studied and modelled. Positivists take a deductive approach to research (Gill and Johnson, 2010). Moreover, known as the objectivist perspective, positivism suggests that reality can be independently observed as it is single and therefore experienced the same way by everyone and stresses on objective knowledge, empirical regularities and deductive tests (Tan, 2002). This makes this particular worldview very objective and as such promote the believe that there is a single reality of nature which means no matter the angle from which it is viewed, it will be experienced the same way by everyone (Creswell, 2013).
- Interpretivism. In contrast with positivisms, the second traditional paradigm, interpretivism assumes that a phenomenon does not obey natural laws but is interpreted based on peoples' understanding of the reality surrounding the phenomenon (Walliman, 2005). Consequently, the interpretivism follows the idea that nature can only be interpreted (Sutrisna and Setiawan, 2016) based on where one is standing. This makes the interpretivism philosophy subjective as people understand things differently (Creswell, 2014). Based on this stance, the interpretivism construct reality based on the person involved making one person's reality different/ likely to be different from another person's due to the difference in observations and perceptions

which are also modified by upbringing, education and training (socialisation). Although applicable to quantitative theories (Fellows and Liu, 2008), the interpretivism paradigm is largely aligned with the qualitative studies as subjectivists tend to use the interpretive, qualitative or idiographic approach to science (Tan, 2002).

- Pragmatism. Aside the two traditional paradigms, there are other non-traditional paradigms which combines the two paradigms to achieve the aims of the research. Saunders *et al*. (2016) mention other paradigms such as realism, pragmatism and the functionalist perspective. These non-traditional paradigms came about due to the realisation of some researchers that the comprehensiveness of reality means no one philosophical perspective is likely to fully explain all issues and as for that reason, there is the possibility of combining the traditional positivist and interpretivism perspectives to enable a better view of the same phenomena (Lee, 1991). From this position, has emanated other combinations of the traditional perspectives and a notable one among these combinations is pragmatism. The pragmatist perspective is a philosophical stance which arises out of actions, situations and consequences (Creswell 2013; Saunders *et al*., 2016). Pragmatism combines both views from positivism and interpretivism to ensure what works best is adopted. Unlike the traditional perspectives, pragmatism places more importance on the problem being studied as well as the questions being asked instead of the methods and as such focuses on the outcome of the research and its applications (Creswell, 2017). For this reason, pragmatists rely on both qualitative and quantitative sources (multiple methods) of data collection, focussing on the practical implications of the research as the best means to answer research questions and problems (Creswell, 2014).

3.3.2. Research ideas

The research ideas that emerged during the early stages of this research are as follows:

- Lessons learnt from existing approaches to the integration of process planning and scheduling techniques can assist the manufacturing productivity in Nigeria
- The commonalities between the process of IPPS and the concept of learning have important value for this research
- Manufacturing companies with manufacturing productivity related knowledge could contribute to the development of new approach to IPPS

- Collaborative functions within manufacturing companies could assist collaboration across process planning and scheduling departments
- Facilitating information sharing between process planning and production scheduling boundaries could contribute to the effectiveness of integration of process planning and scheduling

3.3.3. Research concepts

Manufacturing environment, collaboration between process planning and production scheduling functions, manufacturing productivity and IPPS are the research concepts that assisted the researcher to interpret the set of ideas outlined in section 3.3.2. The review of the literature reported in chapter two presents these and other concepts as part of the main research problem. Consequently, they were combined to form the secondary research questions presented in chapter one.

3.3.4. Theories

Understanding the benefits and limitations of existing approaches to the integration of process planning and scheduling supported the researcher in combining relevant literature with empirical work on the research topic of IPPS to maintain the focus of this research. Bryman and Bell (2015) explains that to address the negative influence of the limitations of theories on validation of research findings, the researcher could employ the literature in place of theories to inform the definition of research questions. They (p. 22) state that theory is latent or implicit in the literature and, therefore, researchers can employ literature as an alternative method to theory.

3.3.5. Hypothesis

The ideas outlined above were arranged around the primary research question and informed by the relevant literature, hypothesis was defined as follows:

> *Addressing the challenges associated with communication between process planning and production scheduling in existing approaches to manufacturing productivity has the potential to increase the efficiency and effectiveness of integration of process planning and scheduling.*

3.4. Methodological approach to data collection and analysis

In addition to practical issues that are discussed in this thesis, theoretical assumptions of the researcher contribute to the process of data collection and analysis carried out to test the hypothesis defined in section 3.3.5. Spencer *et al.* (2014) remark that to assist others to assess the research method employed by researchers and to consider any limitations the method holds, researchers need to provide a thorough description of the design and conduct of the research. To address this, this part of the thesis includes describes research methodology, research design and research methods employed by this research and the issues related to them.

3.4.1. Research methodology

Based on the two traditional paradigms as well as the pragmatist paradigms (described in section 3.3.1), there are also two traditional research strategies and a third. These include the qualitative strategy, which is linked to the interpretivism paradigm, the quantitative strategy, which is linked to the positivist paradigm, and the mixed strategies which is linked to the pragmatist paradigm.

In qualitative technique, the researcher collects primary open-ended data to develop key themes and patterns (Creswell, 2013). Quantitative approach to conducting the research involves studying and analysing numerical data using mathematically-based tools (Creswell, 2013; Maxwell, 2013). The researcher, in this technique, analyses the statistical data. It is largely associated with surveys and experiments (Maxwell, 2013; Teddlie, and Tashakkori, 2009). The combination of qualitative and quantitative techniques creates the mixed method technique that is frequently used in current research. Qualitative and quantitative data are incorporated in research studies that apply this method (Frost, 2011; Teddlie, and Tashakkori, 2009). All the strategies have a means of data measuring phenomenon by proposing a means of data collections and analysis. The descriptions of these research methodologies are as follows:

1. Qualitative strategy

   The qualitative strategy on the other hand is rooted or linked to the interpretivism paradigm or philosophical position and does not necessarily rely on numerical evidence for addressing research questions (Creswell, 2014). This strategy takes an

exploratory approach to research which seeks to develop themes from the qualitative data obtained. Qualitative research deals with experiences, meanings, descriptions and other temporary matters that cannot be quantified (Sekaran and Bougie, 2010). With roots from the interpretivism paradigm, qualitative research is concerned with interpreting and understanding phenomenon through the meanings that people attach to them (Bryman, 2016). Through this strategy/approach a more in depth look at a topic is made compared to the quantitative approach which seeks to numerically conclude. Qualitative methodologies are explanatory in nature and aims to answer questions of 'how?' and 'why?' (Yin, 2014), or to develop themes from the qualitative data obtained (Creswell, 2013). For this reason, it comprises research methodologies such as action research, case studies, ethnographies, and grounded theory and generally seek to collect data in their real or natural settings.

2. Quantitative strategy

   The quantitative strategy for conducting research is mainly linked to the positivist or objectivists' paradigm or research philosophy. This strategy involves numerical and objective measurements to address questions (Yin, 2014). Based on quantitative logic, it entails the numerical representation and manipulation of observation for describing and explaining the phenomenon that observations reflect (Bryman, 2016). It is thus useful in answering research questions relating to what, how much and how many (Fellows and Liu, 2008). The quantitative process of research is deductive in relation to theory and literature. Yin (2014) suggests that, the quantitative research strategy mainly uses numbers to answer research questions. This makes it a useful research strategy to test theory (Saunders *et al*., 2016). It comprises methodologies such as experiments and surveys.

3. Mixed Method

   Beyond the two traditional approaches for conducting research, a number of researchers suggest that qualitative and quantitative strategies can be combined into a single study to ensure a pragmatic strategy is created (Creswell, 2013; Creswell and Plano, 2017). For this reason, a mixed strategy is proposed. This strategy is based on the pragmatist paradigm which does not commit to any one system of reality and philosophy and as such individual researchers are at liberty to choose among the

methods, techniques, and procedures of research that best meet the purposes and needs of the research in question (Saunders *et al*., 2016).

As positivism and interpretivism respectively relate to qualitative and quantitative methods, pragmatism applies to mix methods research and draw liberally from both quantitative and qualitative assumptions (Creswell, 2017; Saunders *et al*., 2016). For the pragmatist, the choice between 'what' and 'how' to research is based on its intended consequences (Creswell, 2017). The underlying principle for pragmatism is 'what works at the time' and as such pragmatic researchers concentrate on selection methods and methodologies that work best for that particular research question.

The definition of research problem in this research in addition to the ontological and epistemological dimensions of its study suggest that the conduct of this research follows a mixed method research methodology.

The main reasons supporting the relationship between qualitative research methodology and the process of data collection and analysis in this research, as outlined by Bryman and Bell (2015), are as follows:

- Principal orientation to the role of theory in relation to research is inductive and includes generation of theory. In contrast with quantitative research, the qualitative research is not concerned with generation of theory rather than testing of an existing theory. In this research. The focus is on investigating the existing theories available in the literature that are relevant to IPPS. Moreover, this research focuses on research findings that can contribute to the development of new theories that could create the opportunities of manufacturing productivity through the process of IPPS.
- The epistemological orientation is interpretivism. The reasons behind individual manufacturing companies' ways of interpreting concepts related to IPPS – such as value, trustworthiness and applicability of it – has significant value in this research
- The ontological orientation is constructionism. In this research individuals' perception and ideas creates social phenomena and their meanings that are being accomplished by social actors, continually. Therefore, its discussion is often in relation to the nature of knowledge that can be produced through social interaction or produced in a constant state of revision

The main reasons supporting the relationship between quantitative research methodology and the process of data collection and analysis in this research are as follows:

- At times, especially during the interview sessions, the researcher and research participants were highly interactive as the goal of this portion of the study is to better understand and capture the participants manufacturing process planning "experience." The concept of "experience" will often be subjective and will require significant qualitative research (Creswell and Plano, 2017). On the other hand, during specific phases in the research, the researcher and the research participants were distant by design as the goal of this portion of the study is to capture/measure objective and quantifiable data regarding particular aspects of the participants housing experience (i.e. quantifiable metrics were used to measure age, gender, production cost and project management planning).
- Although definitions of "manufacturing productivity" and "manufacturing process planning" based on national standards have been utilized, the reality is that any given participant's perspective on these issues is subjective and inherently influenced by a normative concept based on their personal history (Maxwell, 2013). To be blunt, the participants' expectation of improving manufacturing productivity through process planning was likely shaped by their social reality and their lived experience (Creswell and Plano, 2017). This is an unavoidable reality that must be acknowledged, but cannot be controlled as an isolated event (Teddlie and Tashakkori, 2009).

3.4.2. Research design

Bryman and Bell (2015) clarify that the design of a research is very vital as it has a great influence on the validity of the end results. Research design is one of the key aspects of any research or study for the reason that it has a large influence on the reliability the research results. Yin (2014) defines research design/strategy as the logical sequence that connects the empirical data of a study to its initial research questions and, to its conclusions. With this definition, Yin suggests that the research design or strategy plays a crucial role in ensuring the results of the research helps to answer the questions the research set out to achieve. Being the logical sequence between data and the conclusions of the research, it helps to determine the means to collect and analyse data which ultimately helps to answer the research questions posed by the research.

In this research, development and implementation of a new approach to IPPS in manufacturing companies contributes to refining and validating the findings of this research. Yin (2014) emphasises that the key element of research design is its quality. Planning to achieve this is the key motive to employ *case study* as the research design which would assist the researcher to clarify the process of developing a new approach to integration of process planning and scheduling and its implementation.

Yin (2014) clarifies that case study research is a formal method and it is not acceptable to consider it as a tool for exploring other research methods (i.e. ethnography, participant-observation). Miles *et al.* (2014; p.17) remark that case study is not a methodological approach; it is a theoretical perspective of research methodology. Yin explains, other methodological characteristics can be considered as the '*features of case study'*. He suggests that one of the key requirements of case study research is comprehensive planning. Yin's systematic approach to case study design adds to the quality of the research through designing case study protocol and suggests that although conceptual structure is a necessity in research process, the research phenomena evolves along the research process and a procedure limits this gradual development during the research.

Eisenhardt and Graebner (2007) remark that case study approach supports the assessment of theory building and for that reason; it is a valid form of research methodology. Yin (2014) explains that the term 'case study' is used both in teaching and research area and it is important to clarify the meaning of this term. In this research the term 'case study' is used from the research perspective Yin (2014) and Miles *et al.* (2014) emphasise that what to study (e.g. what event or condition) is a very important criterion. This explains that the case should assist the research rather than creating additional phenomenon requiring additional research.

The researcher chosen the *mixed method case study* as the research design because of three key reasons that are as follows:

- The *explanatory* nature and form of the primary research question:

  How do we minimise the limitations to existing manufacturing approaches which integrate process planning and scheduling in developing countries?

Addressing this research question does not require dealing with mere frequencies or incidence of specific events. It does involve a study of the links between IPPS and manufacturing productivity.

- To gain a clear understanding of the factors influencing the process of IPPS (e.g. communication and collaboration between segregated functions), primary data are required as these factors take place within a real-life context. Myers (2013) notes that *primary data* add richness and credibility to qualitative research. Moreover, Avison *et al.* (1999, p.94) argue that to make academic research relevant, researchers should try out their theories with practitioners in real situations and real organisations. Therefore, the researcher needed to employ investigative procedures, interviews with individuals who have problem-centred knowledge and discuss with participating manufacturing companies.
- Manufacturing companies do not provide a collaboration environment where the research could focus on one or two variables related to the IPPS processes and control all the remaining variables beyond the scope of interest. Communication between process planning and scheduling has a human dimension and its related processes are influenced by many behavioural variables such as motivation, politics, etc. which are beyond the control and even access of the researcher.

In addition to the issues discussed above, Yin (2014) explains that there are other issues related to case study approach such as issues related to generalisation, large amount of required time and the volume of data produced through case study approach. In this research, both the theoretical foundations imposed by the research context and the practicalities of its implementation imposed significant challenges that are as follows:

- Determining how many cases would provide the amount and quality of data that would be sufficient to validate the research findings

  Yin (2014) emphasises that multiple case study research helps the researchers to gather compelling evidence and develop research that is more vigorous and reliable. Yin's multiple case study design that in relation to research question consist of set of two or more cases with exemplary outcomes was used in this research to support the development and application of the new approach to IPPS.

- Finding manufacturing companies that were aware of their need for IPPS and were able to engage in collaboration with the researcher towards these aims

  In order to gain interest of manufacturing companies, the researcher prepared what was considered by him and his academic supervisor as an 'interesting business case'. This was used to approach individual managers carefully selected from manufacturing companies in Nigeria.

- Engaging in successful collaboration with those manufacturing companies

  Given the cost and risks associated to a joint venture between a manufacturing company and the researcher in an attempt to study the IPPS problem, the researcher concentrated on achieving a successful outcome for both parties involved.

The description of the challenges associated with the research design in this research suggest that the data collection would be an iterative process that involves the researcher and practitioners acting together on a particular cycle of activities including the identification of the factors influencing a problem and participating in problem-solving. These activities are described in three categories that are: 1) problem diagnosis, 2) action intervention, and 3) reflective learning in the definition of *action research* by Avison *et al.* (1999). Avison *et al.* (1999; p. 94) state that *action research combines theory and practice (and researchers and practitioners) through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework.*

Every effort was made to ensure that neither the challenges associated with mixed method case study research nor the practical issues related to the implementation of the research affected the rigour and relevance of its findings. In doing this, emphasis was put on the validity of theoretical and methodological decisions made during the design of the research.

The key steps of the research and the relationship between them is shown in Figure 3-3.

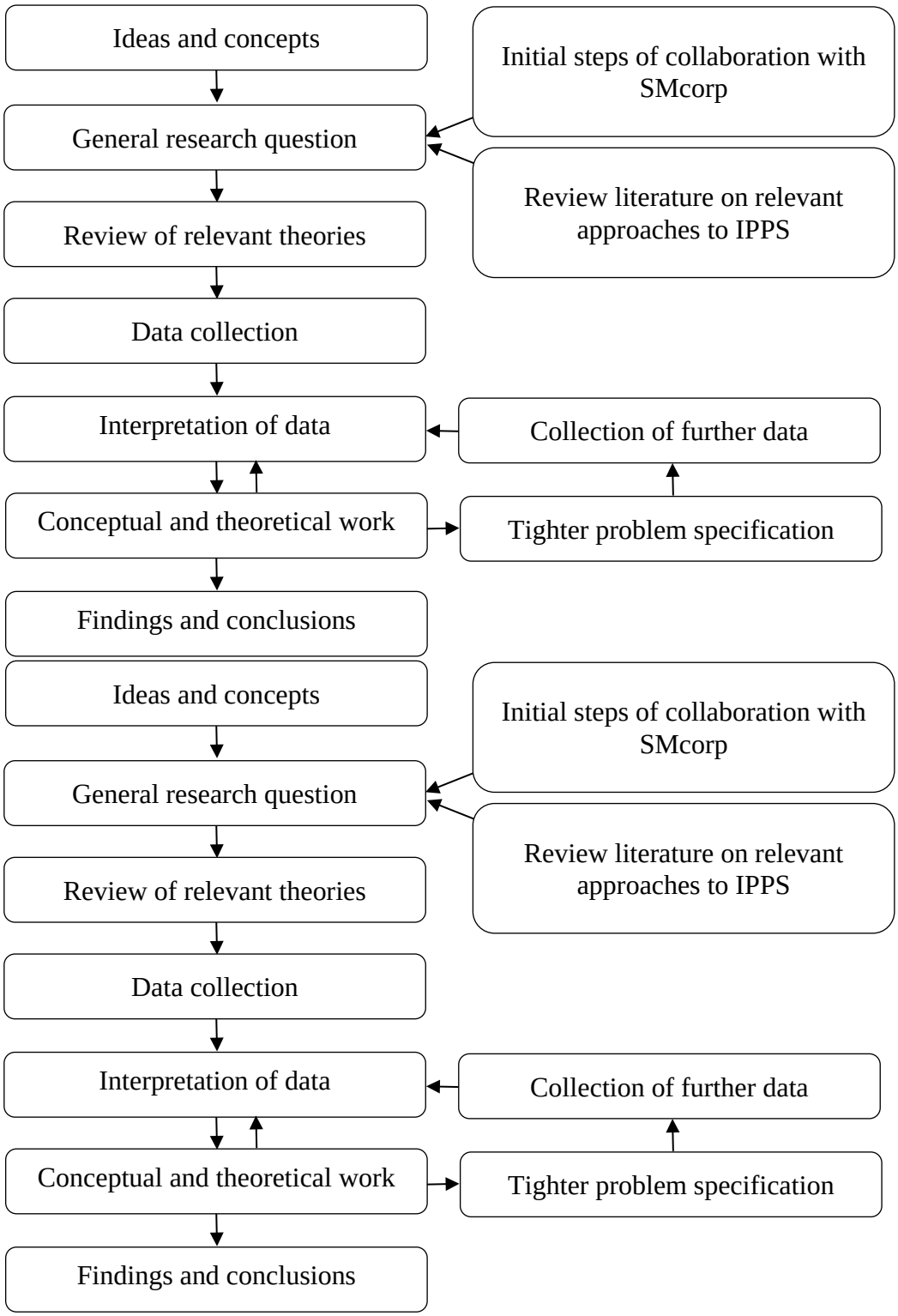

Figure 3-3. An outline of the main steps of the research reported in this thesis (adapted from Bryman and Bell, 2015)

3.4.3. Research methods

One of the benefits of case study research is that it offers access to a wide range of sources of evidence that include documents and artefacts, interviewing participants and observing the development of IPPS processes. Therefore, for data collection and analysis strategies, authors suggest using multiple sources of evidence (Yin, 2014), triangulating these data and using theoretical propositions from the research literature to guide the research (Myers, 2013). This has been the guide for the researcher's approach to data collection. Different methods were used to collect data, a process that was informed by the research questions and the relevant background literature on IPPS.

Yin (2012) clarifies that unlike questionnaires for carrying out a survey, case study research is not limited to only one source of data and having multiple sources of data is one of the advantages of case study research. He explains that there are six common sources of evidence and depending on what source of evidence is available and relevant for studying the case, the researcher can use any combination as well as related sources. These six common sources of evidence in doing case studies which informed the data collection in this research are as follows:

1. Direct observation
    i) Direct observation in a field setting – the focus of this method can be on real-world events, human actions or physical environment.

    Jones and Somekh (2011) emphasise that what is observed is ontologically determined, that is it depends to a very great extent on how the observer conceptualises the world and his or her place within it. They explain that direct observation can be conducted through structured observation or unstructured observation.

    – Structured observation

    One approach is to structure the observation around a schedule prepared in advance. Schedules predetermine the categories of behaviour/talk that will be observed, and are inevitably influenced by the researcher's expectations, so it is usually best to develop a schedule especially for a particular research study.

    – Unstructured observation

Another approach is to sit at the side or back of the room and make detailed notes. In this holistic approach, the researchers are guided by prior knowledge and experience and 'sees' through the unique lens of their own socio-culturally and professional background. Broad decisions are usually made in advance about the kind of things to be recorded, either on the basis of analysis of other data already collected (e.g. interviews) or derived from the focus of the research. It is best to record key utterances verbatim, as this reduces the extent to which intended meanings are obscured, and is usually quicker.

ii) Using a formal observational instrument – the focus of this method is on defining the nature and frequency of interactions between individuals and it can be recorded with an audio-visual device or it can be observed directly.

2. Open-ended interviews (discussion and focus groups are variants of interviews, e.g. open-ended conversations with key participants)

Open-ended interviews (also called 'non-structured interviews provide the researcher richer and more extensive data. This method's flexible format that assists the researcher to learn how case study participants construct reality and think about situations which provides important insights into the case. This method is less structured than open-ended portions of surveys and can be assumed a lengthy conversational mode not usually found in surveys. Open-ended interviews can occur over the course of an entire day, with a researcher and one or more participants.

Meetings and discussions during conducting this research provided the researcher data about the manufacturing companies' perception of integration of process planning and scheduling in addition to the challenges associated with the information and knowledge transfer process across process planning and production scheduling boundaries.

3. Archival records (note-taking)

In addition to direct observations and open-ended interviews, another source of evidence is note-taking which allows the researcher to store data and information. The researcher took notes during discussions and observation process of IPPS. These notes

are a combination of jotted notes presenting a record of informal observations and full field notes followed by initial ideas prior to conversations or events.

4. Documentary evidence

   The manufacturing companies involved in the case studies provided the researcher with secondary data such as administrative documents and prior conducted research. According to Yin (2014) theses data might contain an element of bias and for that reason, this research tread those as other unpublished secondary data.

5. Participant-observation (e.g. filling a real-life role in the scene being studies and being identified as researcher at the same time)

   Jones and Somekh (2011) clarify that participant-observation gain unique insight into the behaviour and activities of those they observe because they participate in their activities and, to some extent are absorbed into the culture of the group. Disadvantages include that they may distracted from their research purpose by tasks given to them by the group, and note-taking becomes much more difficult and may have to be done after the event, ideally the same evening. It is also necessary to guard against becoming too immersed in the group's culture and losing sight of alternative perspectives.

6. Physical artefacts (repository of information)

   A final source of evidence is a physical artefact. Technological device or other physical evidence may be observed or collected as part of a case study that has been used extensively in anthropological research. This type of evidence has less potential relevance in the most typical kind of case study. However, when relevant, it can be an important component in the overall case.

The researcher collected two more sources of evidence during the conduct of this research that are as follows:

1. Semi-structured interviews

   Creswell (2013) explains that an interview is the means to gain several research realities. Interviews are useful in revealing how other people think or feel about their experiences (Frost, 2011). The research, therefore, elicits more details and

information (Creswell, 2013). According to Creswell and Plano (2017), interviewers that follow suitable procedures successfully collect data for comprehensive analysis. Creswell (2013) remarks that the factors that has to be considered by the researcher about the interview method are as follows:

- Using purposeful sample process to identify the participants
- Choose semi-structured interviews as suitable for the study
- Record all interviews to transcribe them later
- Design an interview protocol form for use
- Conduct a pilot test to test the interview questions and prepare the last script after making necessary adjustments
- Identify the location for interviews
- Obtain the consent from each participant

Saunders, *et al*. (2016) remark that semi-structured interviews facilitate room for repeating questions, interviews are flexible and participants explain meanings in the subject under investigation. Moreover, personal contact increase response opportunities. Creswell and Plano (2017) emphasise that semi-structured interview questions have to be properly constructed to ensure that the survey was valid and reliable. A summary of strengths and weaknesses of this source of evidence is listed in Table 3-1.

Table 3-1. Semi-structured interviews: strengths and weaknesses (Yin, 2014; P 106)

Source of evidence	**Strengths**	**Weaknesses**
Semi-structured interviews	- Focuses directly on case study topics - Insightful – provides explanations as personal views (e.g., perceptions, attitudes and meanings)	- Bias due to poorly articulated questions - Response bias - Interviewee gives what interviewer wants to hear

With the interviews carried out with some employees in the Nigerian manufacturing companies, it is easier to comprehend the complex production processes as well as gain detailed viewpoint on their succession and strategic planning processes. To gather sufficient data for answering the research questions presented in the first chapter, semi-structured interviews were. Interviews were conducted with personnel involved with process planning within the manufacturing companies used for this

research. Specifically, interviews were conducted with employees in managerial positions to assist the collection of an in-depth knowledge of the activities of the manufacturing companies. The purpose of the semi-structured interviews was to collect data which provides intuition, knowledge and understanding about improving manufacturing productivity through improved manufacturing process planning and production scheduling of manufacturing companies in Nigeria. Moreover, the semi-structured interviews focused on gaining a better understanding of why the companies use a particular kind of process planning technique as well as how production scheduling is undertaken.

2. Questionnaire

In order to address the need of the research questions, questionnaire was designed in this research. Bryman (2016) clarifies that some of the advantages of using questionnaire as a data collection techniques are as follows:

- Flexibility. The flexibility of this technique assists the researchers to employ it regardless of the diversity of theoretical positions and research questions
- Relatively cheapness of adapting this technique
- Speed or ease of administration

Saunders *et al*. (2016) clarify that the participants answer the questions distributed questionnaires and, after providing completed answers, the researchers describe all responses provided. Creswell and Plano (2017) emphasise that, similar to the semi-structured interview questions, it is important to properly construct the questionnaire in order to support the validity and reliability of the data collected through this method.

Using questionnaire was employed in this research to better define attitudes, behaviour and opinions held by company employees regarding manufacturing process planning and production scheduling. The questionnaire administered contained multiple choices with predefined classes for the participants to make selections; thus, classifying the responses into predefined choices offer statistically inferable data. Creswell (2013) explains that the classification allows the researcher to measure the importance of the results obtained on the general population under study and changes of the participants' behaviour, attitude and opinions over time.

3.5. Ethical issues

While carrying out any investigation with human subjects, the researcher must know how the entire research affects the society and all participants (Maxwell, 2013). As such, the research need to adhere to ethical concerns by acting accordingly (Frost, 2011). According to Kumar (2005), accumulating information with no participants expressed willingness, knowledge and informed consent in unethical. This study thus ensured anonymity, informed consent and confidentiality.

The issues of ethics when conducting research, as suggested by Creswell (2013) and Maxwell (2013) are as follows:

- The research should be considered in terms of its usefulness in contributing to the advancement of human knowledge. This principle is fundamental to all the rest. If the research has no purpose, it should not be done.
- The researcher is responsible for his or her subjects and this principle is considered valid with respect to all types of research using human subjects. Even research as innocuous-seeming as a market survey for coffee –brand preferences require that subjects 'rights not to be violated. If a subject prefers not to participate or prefers that it not be general knowledge that he uses a particular brand of coffee, this preference should be respected by the researcher.
- Subjects should be willing to take part in the study after being informed of all aspects of the research that might influence their decision. Subjects should have all the information about the study that they need to make a decision about participating. They should not be misled.
- Subjects have the right to insist that their anonymity as participants in the research be observed. They should be assured that they will not be identified by their performance or the nature of their participation. The researcher also has the responsibility of ensuring that information about the subjects and their responses remains confidential and that it is used for no purpose other than the experiment for which it was intended.
- Subjects must not be coerced into participating. This principle had been violated consistently before ethical codes for researchers were formalized.

The researcher is fully aware of the importance of adhering to the University of Wolverhampton ethical codes and the rights and safety of the participants was not being

compromised in anyway. So, the ethical concerns addressed were informed consent and confidentiality and anonymity.

3.5.1. Informed consent

Informed consent was considered. The researcher sought informed consent before administering the questionnaires to the participants. Failure by the research to notify the participants about the study according to Creswell (2013), shows disrespect to personal autonomy. The study allowed all employees to participate voluntarily after signing the consent form. No individual was forced to participate in this study.

Informed consent is significant before subjects partake in human research. So, the participants need to know what the researcher asks them to do, benefits and related risks before agreeing on participation. To provide the potential participants information on the study, an informed consent form was sent to the participating manufacturing companies in Nigeria. This form contained the information that are as follows:

- Reasons for carrying out the investigation
- The role of participants
- Selection procedures
- Voluntary participation and opportunity not to partake in the study without providing explanations
- Specific information required from the participants
- Guarantee of confidentiality and anonymity
- Storage of the collected data
- Use of the data or information gathered

Before engaging in the research, all participants signed the consent form. No one was forced to participate since it was voluntary. Questionnaires returned with completed responses suggest informed consent and voluntary provision of the responses.

3.5.2. Harms and risk

There are many varieties of harm to participants from blows to self-esteem or *looking bad* to others, to threats to one's interest, position or advancement in organisations and so on (Miles *et al.*, 2014). In the context of this research, participants might feel insecure about the value of their knowledge, they might be afraid of negative consequences (e.g. their insight and

ideas might be criticised or ignored), moreover they might be worried about losing ownership of their knowledge or losing position. All these can have negative influence on the participant and the effectiveness of IPPS. Therefore, the researcher made every effort to ensure that these issues are addressed throughout the research.

3.5.3. Honesty and trust

For researchers, in addition to being honest in the course of their research, it is important to maintain reasonable trust among the participants of collaborations (Bstieler *et al.,* 2015; Denscombe, 2007). This supports efficient and free-flowing knowledge transfer and contributing to problem-solving through discussions. He emphasises that facilitating this trust is the role of the collaboration leader who can create an environment that motivates participants' engagement in contributing their knowledge. This research considered the significance of this trust among the participants on the success of collaborations with manufacturing companies. To build this sense of trust, this researcher clarifies the purpose of the collaboration for the participants and its benefits for the domain that includes each and all of the functions in manufacturing companies and manufacturing industry of Nigeria.

3.5.4. Right to privacy, confidentiality and anonymity

Miles *et al.* (2014) affirm that in research practice, the terms privacy, confidentiality and anonymity are often confused or used interchangeably, Sieber (1992, pp 44-45) describes the distinctions among these terms in research practice that are as follows:

- Privacy. Privacy refers to individuals and their interest in controlling over other's access to themselves. Miles *et al.* (2014) explain that this involves preservation of boundaries against giving protected information or receiving unwanted information
- Confidentiality. Confidentiality is an extension of the concept of privacy and it refers to a form of informed consent agreement between researcher(s) and an individual or an organisation that include the ways of using data they provide to the researcher. Denscombe (2007) explains that ensuring confidentiality supports the development of trust among the participants. Participants who are ensured that their knowledge and experience will be treated as confidential by the other participants in the collaboration contribute their true knowledge and experiences. In this research, potentially sensitive data and information has been omitted or altered in order to maintain the confidentiality of the individuals, organisations and their businesses.

- Anonymity. Anonymity means that the researchers never specify the source of data that might clarify the identities of individuals or companies. In this research, the names of individuals and manufacturing companies involved in the conduct of this research are kept anonymous.

Consequently, to make data anonymous, the researcher has to remove key identifiers such as names. Other vital information that need protection include gender, age, length of service, membership of associations and job titles. The identities of the participants have been protected in this research study. In this study, groups, employment units and manufacturing companies were protected to ensure anonymity. Data collected is used in the way only known to the researcher.

In the questionnaire, the participants were instructed not to provide identifying information like employer's address, name, phone numbers, social security numbers, or photo. The researcher used fictitious names for the participating manufacturing companies in this thesis to preserve confidentiality and anonymity of the participating companies and individuals. Other actions taken by the researcher to increase the confidentially level are as follows:

- Securing the data and documents in locked computer and location
- Limiting accessibility to the identifiable information- only the supervisor saw the data
- Removing any identifiers e.g. addresses and names from the returned survey questionnaire
- Using study codes thus avoiding association with identifying information

3.6. Summary

Once the research questions had been defined and the theoretical assumptions and issues affecting the data collection and analysis had been understood, it was necessary to have a plan for the investigation. Such a plan constitutes a research design and provides a framework for the collection and analysis of data. Kerlinger (1986; p.279) describes a research design as

> *"a plan, structure and strategy of investigation so conceived as to obtain answers to research questions of problems. The plan is the complete scheme or program of the research. It includes an outline of what the investigator will do from writing the hypothesis and their operational implications to the final analysis of data".*

The research design outlined during early stages of the research was limited by the practical issues related to its implementation, e.g. establishing joint ventures with manufacturing companies that were still to be found, as described in this chapter

The collection of data through a multiple case study will be detailed further as part of chapter Five.

This research follows the general view of the research design as much as possible, and ensures that the practical issues related to its implementation did not affect the rigour and relevance of its findings. Therefore, emphasis is put on following the theoretical and methodological decisions made during the design of the research.

CHAPTER FOUR

4. A new approach to integration of process planning and scheduling in manufacturing companies

This chapter presents a new approach to integration of process planning and scheduling in manufacturing companies that is based on assisting the gap of information flow between these two traditionally segregated functions to facilitate energy saving and maintain manufacturing productivity. This approach has been developed to address some of the key limitations of existing approaches to integration of process planning and scheduling as identified in the relevant literature. Moreover, this chapter includes a summary of empirical origins and theoretical foundations that informed the fundamentals of this new approach. In addition, it describes a method that can assist manufacturing companies to implement the proposed approach followed by details of a sample application of the new approach in real manufacturing companies in Nigeria.

4.1. Introduction

4.1.1. The empirical origin of the new approach to IPPS

The collaboration between the researcher and SMcorp, as introduced in chapter one, forms the beginning of the development of the new approach to integration of process planning and scheduling. SMcorp is a leading manufacturer of nut screws, Rivets head and bolts for metal building manufacturers, steel fabrication construction, water works and equipment manufacturers. SMcorp manufactures both non-standard and custom fasteners, operating numerous centres for distributing bolts, nuts and other standard fasteners in Nigeria. Such a diversity offer the Nigerian customers certified quality, faster delivery, superior services and strategic advantage.

SMcorp promises superior quality assurance. With respect to quality control, the main aspects considered are allocated diameter size, number of groves per inch, allotted pitch and designated shape of groves. The firm manufacture and distribute highest quality items since it

has certified distribution centres and manufacturing facilities. To make sure most products manufactured meet the strict quality criteria, SMcorp conducts autonomous third-party testing and in-house testing. In addition, SMcorp measure quality from raw material purchase to product installation by the erectors and dealers.

To ensure improved production capacity, SMcorp ensure that experienced personnel committed to craftsmanship and quality operate high speed threads, latest presses and bolt-heading machines. SMcorp's production machine capacities subsume drilling, milling, bending, slotting, turning, nothing and flattening. The core manufacturing processes in SMcorp include shearing, bending, turning, drilling, grinding, threading, boring, knurling, welding and heat treatment.

To remain competitive, SMcorp use lean manufacturing to address resource wastage, thus generally improving manufacturing productivity. Through this methods, SMcorp maintain its market share, guarantee customer satisfaction and quickly bringing products to Nigerian markets. Identifying work flow linked to manufacturing bolts and nuts, including communication procedures, technology resources, people and processes essential in the production process is a key practice for improving manufacturing productivity. Moreover, SMcorp monitors the information gathered from some process improvement projects aimed at implementing improvements throughout all manufacturing operations. SMcorp has an intranet website where its employees publish business cases, balanced scorecards and reports on performance. Thus, employees of SMcorp access suitable training and information on implementing key procedures geared towards improving manufacturing productivity.

In this field research, formulating the information need came first and it was followed by identification of possible resources containing the required information and then the process of extracting and absorbing the information and knowledge from these resources. Subsequently, data collected showed that the need for efficient communication between process planning and production scheduling functions is as significant as information and knowledge transfer between other functions of the manufacturing company. In an attempt to also provide SMcorp with a short-term tangible outcome as a result of the collaboration, the researcher agreed to develop a system that could be used to support the process of delay diagnosis on shop floor. Such a system would be based in the development and use of Bayesian network modelling which could represent the relationships between shop floor delays, their symptoms and root causes.

It became clear that constructive improvement in interactions between process planning and production scheduling noticeably increases the chances of reducing energy consumption, improving SMcorp's performance and enhancing its productivity. Production planning staff are one of SMcorp's primary sources of information about all issues related to supporting production on the shop floor with the discrete process plan. This increased the awareness, at management level, of the need to share the problem-centred knowledge of production scheduling (PS) staff on a regular basis.

Considering the knowledge-intensive production scheduling function being the communication channel between the shop floor and process planning function, this study provided the opportunity of illustrating the potential need for information flow practices and across relevant department within this manufacturing company.

In addition to analysing PS staff's description of their problems at the shop floor of SMcorp, the researcher conducted a series of collaborative meetings and he participated, as observer, in discussion sessions that involved employees and managers from process planning and production scheduling functions to identify the factors influencing lack of efficient communication between the functions. This collaboration with the researcher and the new approach to integration of process planning and scheduling was perceived by the SMcorp as successful approach to problem-solving.

A review of the literature was then conducted in an attempt to identify other work that was relevant for the formalisation of the strategy adopted. The literature review, included in chapter two, explored the potential advantages of combining collaborative leadership and assisting group meetings and interviews for the purpose of overcoming the known limitations of current approaches to IPPS in manufacturing companies as specified in section 2.4 of this thesis.

4.1.2. The extent of the new approach to IPPS

To better understand the need for facilitating collaborative information and knowledge transfer across diverse functions within one domain in developing collective solutions – from which all the functions of SMcorp would benefit – it is necessary to have a clear recognition of boundaries that keep apart process planning and production scheduling functions which performance have direct or indirect influence on the performance of the manufacturing company as a whole.

This collaboration approach helps concerned diverse functions in a domain to develop models describing the factors initiating any given problem affecting that manufacturing company. This approach is about empowering process planning and scheduling functions to make a difference in the performance through providing them with ways to collaboratively find the most effective solution for manufacturing productivity.

Integration of process planning and scheduling involves facilitated open environment – where there is no separation between research and practice – for information and knowledge transfer that is open to functions to meet and communicate current problems. Participants in collaborations engage in developing emerging solutions driven by real-life problems while information and knowledge transfer and problem-solving occur effectively.

Collaboration between process planning and scheduling functions does not include predetermined outcome but creates an environment within which diverse functions work together as a team and problem resolution and possible solutions emerge from their collaboration. Therefore, skilful leadership is of critical importance for creating and holding such collaborations.

4.2. EC-FIKT: A method for implementation of the new approach to IPPS

4.2.1. Characteristics of Effective Communication through Facilitated Information and Knowledge Transfer

Successful facilitation of collaboration between process planning and scheduling functions with the aim of developing collaborative problem-solving, develops solutions addressing the problems at the scale it is designed for. Regardless of availability of resources, the success of information and knowledge transfer depends on effective use of resources including time and experience. Burck (2014) remarks that depending on the complexity of the problem and process of information and knowledge transfer, the duration of IKT can last from hours to days. In order to assist manufacturing companies to understand the process of applying the new approach to IPPS in practice, this research has designed a method that defines a set up steps that manufacturing companies can run. In this research, this method has been called EC-FIKT to stresses the strong relationship between the method and *Effective Communication-Facilitated Information and Knowledge Transfer* which highlights the significant impact of each of these steps on the success of implementing IPPS. These steps are as follows:

1. Creating credible problem resolution

The field research at SMcorp suggested the process of creating credible problem resolution helps the individuals to structure their understanding of the key factors influencing the problem. In other words, collecting different perceptions of the problem facilitates understanding the interconnectedness of different factors that develop the problem affecting the domain. In this step holistic understanding of the factors influencing the creation of the problem facilitates developing holistic resolution of the problem. Schwarz (2002) suggests that facilitating learning more about the participants' experience around the problem can support minimising defensive behaviour among the participants who withhold judgment and investigate others' reasoning. This understanding prepares the analysis leading to identifying required problem-centred information and knowledge for effective communication across process planning and scheduling functions boundaries.

2. Communicating perceptions of the problem across process planning and scheduling functions boundaries

Polanyi (1962) emphasises that tacit knowledge consist of series of conceptual images embedded in individual's mind and the key to effective problem-solving is to enable participants to illustrate visual representations of their tacit knowledge and make it explicit in collaborative processes. In addition to converting tacit knowledge into explicit knowledge, Nonaka and Takeuchi (1995) affirm that *express the inexpressible* it is critical step in the implementation of IKT across functions. They explain that this step involves using figurative language to presents and share perspectives. They emphasise that figurative language or models of domain knowledge can take the form of analogy or metaphor, anecdote or diagram to facilitate creating common understanding between individuals with different identities.

3. Identifying and engaging individuals with problem-centred information and knowledge

The field research suggests that involving individuals from the two different process planning and scheduling functions, who have experienced specific problem or knowing the factors influencing that problem through experience, would contribute to the effectiveness of the communication and problem-solving. Morris (2013) remarks that participation of different and diverse functions in problem-solving approaches can have both positive and negative effects on the process and outcomes of the approaches. He emphasises that clarifying the

factors associated with functions engagement that affects the success or failure of information and knowledge transfer should be the priority in developing and implementing communication across function boundaries.

Consequently, EC-FIKT considers addressing these factors through some IPPS techniques that are as follows:

- Managing the impact of conflicting priorities

  Breese (2012) affirms that conflicting priorities is one of the problems related to intra-organisational communication. Bosch-Rekveldt *et al.* (2011) explain that different functions have varied expectations and desires that add to the complexity of engaging them in collaboration. Morris (2013) emphasises that clarifying the purpose and benefits of the collaboration for the involved functions expands their willingness to engage in collaboration.

- Moderating the impact of information and knowledge diffusion across boundaries

  Manufacturing company's functions have the sense of protecting the deployment of the department's information and knowledge across boundaries. Ernst and Chrobot-Mason (2010) emphasise that to achieve effective collaboration across boundaries, it is important to supports the functions' engagement in collaborative problem solving in line with maintaining intergroup satisfaction with the IKT practice.

- Creating transparent environment

  Transparent problem solving environment facilitates learning about different effects of the problem on each stakeholder groups and their concern through sharing experiences. Ernst and Chrobot-Mason (2010) asserts that transparent collaboration environment within which functions learn about other functions' values, priorities, expertise and needs improves creating collaborative solution.

The key roles in the implementation process of effective communication through facilitated information and knowledge transfer are as follows:

1. The IPPS leader

Ansell and Gash (2012) affirm that IPPS leadership has embedded facilitative meaning and is essential in the process of addressing challenges associated with intra-organisational

communication. Diverse function identities and perception of the problem challenges the effectiveness of collaborative approaches to problem solving. Facilitative leader helps the functions in creating common direction and expectations and supports developing shared overall interest but without neglecting that the diverse experiences and perspective are required to enhance the effectiveness of information and knowledge transfer. Therefore, differentiating and coordinating has to occur simultaneously.

Schwarz (2002) explains that skilled leader approach is systemic approach to group facilitation; it significantly contributes to the effectiveness of group collaboration. Leading intra-organisational collaboration is a reliable approach to improving the effectiveness of the collaboration; however, it has its limits and challenges associated to these limitations. Schwarz (2014) recommends that understanding the nature of these limitations supports the IPPS leader in altering process and structure of the collaboration, to a feasible extent, towards minimising the limitations affecting the effectiveness of collaboration.

Field research at SMcorp and review of the literature, in particular, as discussed in section 2.4.5, guided this research in describing key roles of IPPS leader which have direct influence on the effectiveness of intra-organisational communication in three categories that are as follows:

1) **Evaluating** problem-centred information and knowledge and selecting individuals from process planning and production scheduling functions

Deciding problem-centred or problem-related information and knowledge empowers the effectiveness of IPPS. Locating the required information and knowledge and accessing individuals from process planning and production scheduling functions who have problem-centred information and knowledge form the *evaluating* role of the IPPS leader. Involving the right individuals to assist identifying the relevant information and knowledge resources is critical in this stage and the absence of links between process planning and production scheduling functions adds to the complexity of this initial role.

2) **Enabling** information and knowledge transfer across process planning and production scheduling function boundaries

Facilitating the information and knowledge transfer environment opens the lines of communication between process planning and production scheduling functions. Schwarz (2002) remarks that one of the core assumptions for effective IKT is that each participant has

some relevant information and knowledge and, therefore, they have some experience that is required to understand and address the problem. He explains that assuming that each participant has relevant information and knowledge that would affect the understanding of the problem domain inspires information and knowledge transfer.

Schwarz (2014) remarks that facilitating mutual learning helps creating collective mind-set that elaborates the information and knowledge transfer between the functions. He clarifies that collective mind-set enables the functions with different perspectives on the specific problem to share their problem-centred information and knowledge and explain the factors that influenced their experiences.

IPPS leader assists functions to share all their relevant experience about the problem in hand by sharing specific information and knowledge that involves their function's needs and interests and, in addition, explaining the reasons that their experience is relevant to the area of manufacturing productivity. This approach creates learning environment for the functions that supports them in creating collective understanding of factors influencing the problem in their domain.

3) **Engaging** functions in information and knowledge transfer

Katzenbach and Smith (2001) describe that preparatory activity helps speeding the formation of the group and facilitation helps the engaged group in problem-solving and information and knowledge transfer to function more efficiently. Peschl and Fundneider (2014) emphasise that information and knowledge transfer is a result of interaction between different groups within highly complex network. Therefore, facilitated IKT environment is required to support the process of information flow through integrating several dimensions of the environment including physical, social, cognitive, epistemological and technological.

This research proposes the *triple E model* that suggests these three main roles are interconnected and are not a series of independent roles and as illustrated in Figure 4-1, they are cyclic roles – the IPPS leader can revisit the past evaluating, examine the inconsistencies or conflicts in the past enabling and engaging, and at the end, transfer the information and knowledge created across process planning and production scheduling boundaries in the implementation of EC-FIKT.

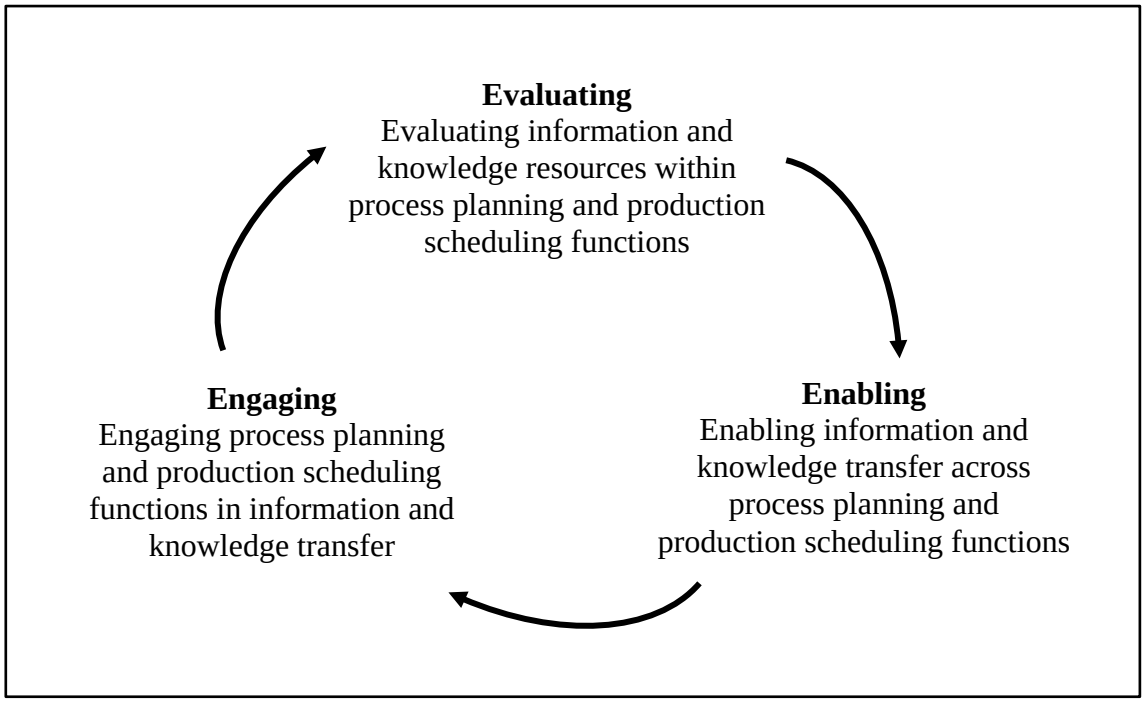

Figure 4-1. The cycle of IPPS leader roles in the implementation of EC-FIKT: Triple E model

2. Individual participants

This research focused on involving individuals with problem-centred information and knowledge in the process of IPPS. This method does not exclude individuals with relevant expertise. In contrast, it aims at gaining insight from individuals such as managers in addition to gaining insight from experts. During the field research, analysing production scheduling function's problems helped the researcher to identify the causes of their dissatisfaction with process planning function. Consequently, this research uses the term problem-centred information and knowledge to omit the skills and expertise focus on their experience which could contribute to assisting IKT and problem-solving. However, this research specifies where a particular skill or expertise was required and the research engaged experts in the process of IPPS.

Effective communication through facilitated information and knowledge transfer has been used throughout the implementation and validation stages of this research. However, it is important to mention that this method does not represent the only mechanism by which the new approach to IPPS proposed by this research can be implemented. The flexibility of this new approach enables the IPPS leaders to adapt its implementation to the context and the circumstances in which it is to be applied.

4.2.2. The key steps of EC-FIKT

Conducting an IPPS project based on collaborative problem-solving as defined by EC-FIKT comprises two key phases that can be divided into four key stages. The outline of these are as follows:

1. Designing the IPPS project

It is possible to run single one-off or series of collaborative sessions over a period depending on the problem it is planned to address. Each collaboration session might require different skilful and selective leadership. The time required for designing the collaboration sessions depends on key factors including but not limited to the time required for identifying, selecting and inviting individuals who have problem-related information and knowledge in the concerned manufacturing company. Designing the collaboration sessions begins with exploring the purpose and objectives of the collaboration and they might be refined throughout the design process prior to the collaboration. The design process of collaboration sessions is iterative process of consulting experts from process planning and scheduling functions and many aspects of design process develop gradually during this phase. Consequently, engagement of different functions, additional facts and inputs will be required.

1.1. Project initiation. The design of the collaborative sessions needs to have its clear and compelling purpose to assist the achievement of the collaborative session's purpose. Therefore, the manufacturing company and IPPS leader(s) agree on the feasibility of implementing the method, its expected outcomes and the process of its application at this stage. Moreover, it is important to identify and involve the functions who have major influence on the elaboration of the problem and different functions who are affected by the current problem in the manufacturing company. Selecting right individuals from these functions to participate in the IPPS is a key outcome of this stage.

1.2. Project preparation. After identifying and selecting the right individuals, the IPPS leader(s) need to plan effective approach for inviting the functions to engage in collaboration. It is important to ensure the groups that their information, knowledge and ideas will be valued and support the outcome of the collaboration and they will benefit from the outcome. Moreover, Designing and implementing the structural

components of the collaboration involves planning and scheduling. In addition to creating conceptual environment that coordinates participation, physical environment conductive to coordinating participation is essential.

2. People-based information and knowledge transfer
   2.1. Effective communication. During these meetings, consulting the problem between the IPPS participants and creating the common vision settles clarifying the current state of the problem and leads to deciding on required information and knowledge stocks. Creative brainstorming between the functions is required to help the individuals to share emerging ideas and identify the information and knowledge available within each function that the collaboration can benefit from in terms of solving the problem.
   2.2. Review and reflect. The IPPS leader(s) lead the participants to review and evaluate their findings. The feedback loop assists the participants to reflect the new insight and knowledge and refine, if required, the development of the components of final solution.

The relationship between these phases and their key stages is shown in Figure 4-2.

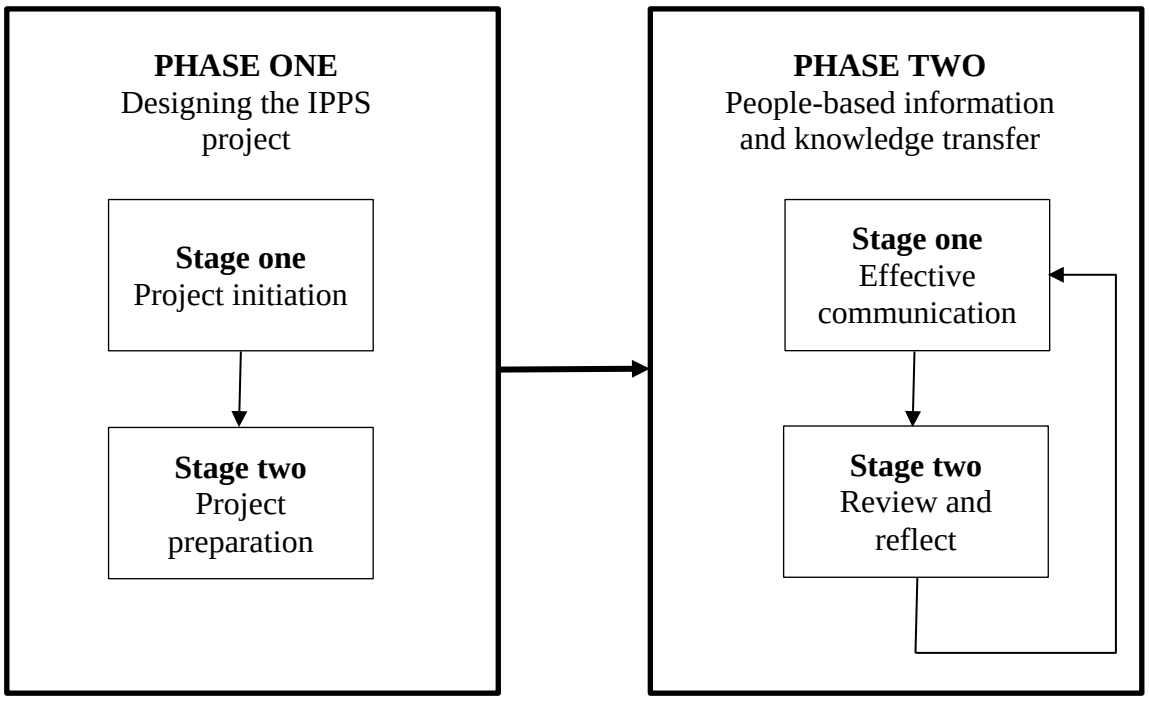

Figure 4-2. Key phases and embedded stages of implementation of EC-FIKT

The remainder of this chapter outlines the approach to implement each of the EC-FIKT phases. These definitions and descriptions are informed by the theoretical issues influencing

the method and the experience gained by applying and refining in the field, which will be discussed in chapters five and six.

Phase 1. Designing the IPPS project

Phase 1 – Stage 1. Project initiation

An IPPS project can have some cost for manufacturing companies. This might include intangible cost such as encouraging employees to participate in sharing their experience about a particular problem on the shop floor with the manufacturing company or freeing a number of key employees from their core work in order to participate in the IPPS meetings or tangible cost such as appointing internal experts or external researcher(s). manufacturing companies can minimise this form of cost and benefit from accessing the expertise and knowledge they need without having to hire full-time experts. For example, research students and staff in universities seek opportunities to apply or create theories and manufacturing companies need solutions for complex problems that could not be addressed through company' resources. Consequently, collaboration between researcher students from universities and manufacturing companies is one of the methods that strongly motivate both parties to engage in collaboration and contribute to business improvement of one another. This method, significantly, contributed to the development of the new approach to IPPS in this research.

The starting point for a IPPS project is the assumption that the manufacturing company is aware of its benefits and determined to commit the required resources to its implementation. Therefore, to prepare for the implementation of EC-FIKT, the aims of the project initiation stage are as follows:

- The key purpose of collaboration between internal functions of a particular manufacturing company is bringing them together to achieve solutions for problems in their domain. Therefore, it is important to develop a mutual understanding between the manufacturing company and IPPS leader(s) about the need for and expected outcomes of IPPS process. The specification and availability of the information and knowledge required for EC-FIKT depends on the ability of manufacturing company and IPPS leader(s) in understanding the purpose of IPPS.
- The collaboration designing team consist of representative of concerned manufacturing company and IPPS leader(s). Bringing together critical bodies of

knowledge in the collaboration design phase, specifically in the initiation stage, have significant influence on the success of IPPS process

– Selecting the right groups of individuals from relevant functions for IPPS. IPPS meetings bring together diverse and segregated functions that consist of functions influencing the current problem in a domain and functions affected by that problem.

In order to achieve such aims, manufacturing company representative(s) and IPPS leader(s) are expected to discuss and agree on the following issue:

1. Developing a clear purpose with IPPS team and identify information and knowledge domain
2. Engaging the right people in the design phase
3. Selecting the right groups within functions for IPPS

Part one. Developing a clear purpose with IPPS team and identify information and knowledge domain

It took two discussion meetings between the research group and SMcorp representatives to agree on purpose of IPPS and to identify information and knowledge domain. In the first meeting, the participants were as follows:

– The research group
  - The researcher (PhD candidate from University of Wolverhampton) – IPPS leader
  - Quality control analyst from SMcorp – Information and knowledge transfer (IKT) expert – IPPS leader on the manufacturing company side
– SMcorp representatives
  - Plant manager
  - Master scheduler – IPPS leader on the manufacturing company side
  - Quality control analyst
  - Production supervisor
  - Production technician

The researcher used structured observation method for this meeting. His field role was mainly observer as participant and he used the note-taking method to record the observation and key points discussed during the meeting to address the initial ideas prior to this meeting. He noted the representatives' approach during explaining SMcorp' problem on the shop floor. During

this meeting, there was reluctance to accepting SMcorp encounters delays on the shop floor for the reason that the representatives needed to dismiss any negative opinion that would challenge the quality of manufacturing provided by SMcorp. The researchers needed to break down this usual pattern and comfort the representatives that investigating and accessing any source of data that represents the reasons of production delays will help finding causes of low level of productivity at this manufacturing company which claims providing the best production quality and these data will remain confidential in any document produced for other parties.

In the second discussion meeting, the participants were as follows:

- The research group
    - The researcher
    - IKT expert
- SMcorp representatives
    - Master scheduler
    - Production manager
    - Production supervisor
    - Production technician
    - Inventory officer

The field role of the researcher was complete participant. During this meeting the purpose of this collaboration was clearly identified and both of the research group and representatives from SMcorp understood and accepted the purpose. The purpose was outlined to analyse a sample of the interaction between production scheduling staff and other functions in order to identify any information and knowledge-related issues that can be addressed by SMcorp in its attempts to improve their production scheduling. This analysis of data already available at SMcorp looking for issues related to information, knowledge and their transfer with relevant functions was likely to lead to a set of recommendations for actions.

At this stage of effective communication through facilitated information and knowledge transfer, the researcher proposed set of steps for identifying factors influencing delays on the shop floor. The steps and relationship between them are illustrated in Figure 4-3.

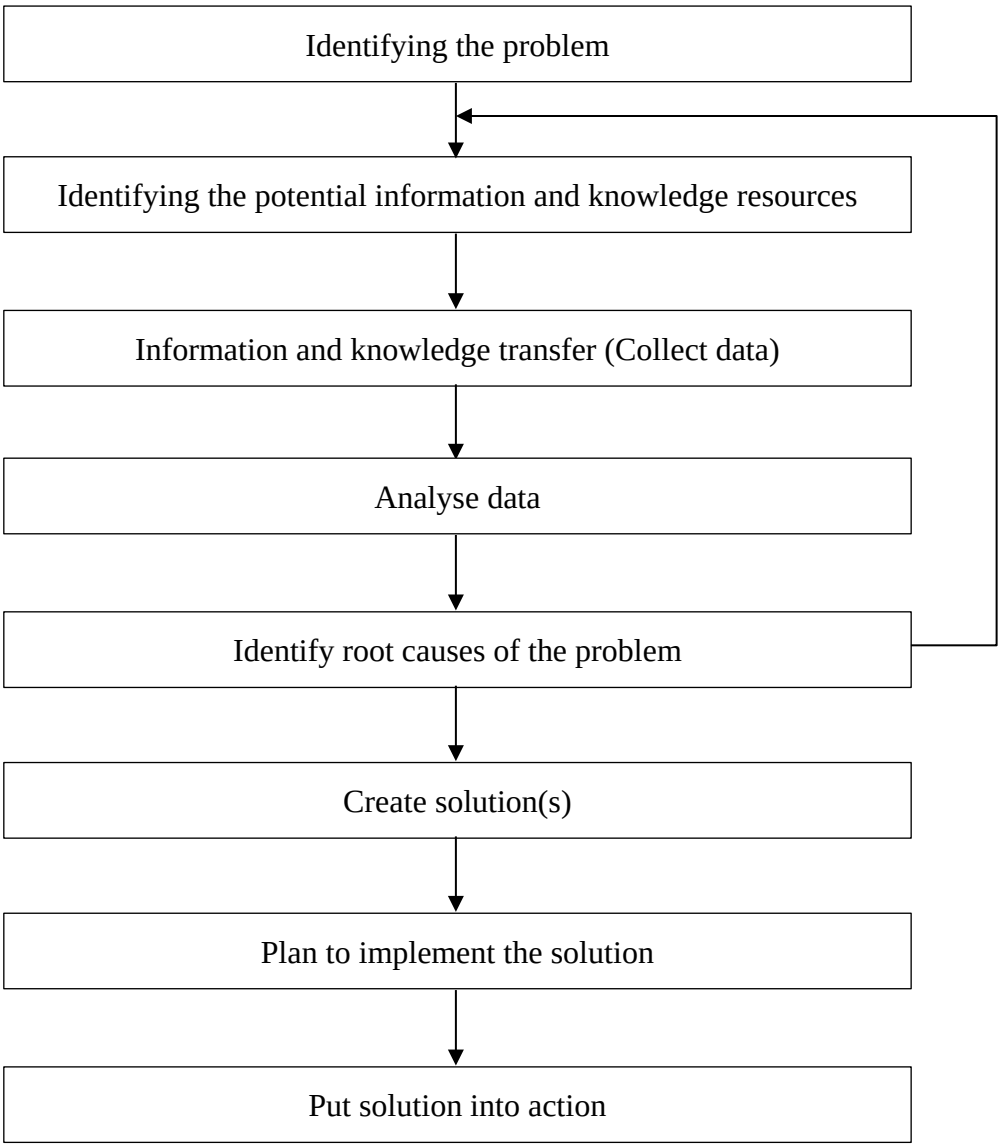

Figure 4-3. Key stages of identifying root causes of production scheduling problem proposed by this research

It was agreed that this collaboration would achieve three deliverables that are as follows:

1. Write a document to report the key issues found
2. Present the findings to SMcorp representatives
3. Contribute to the outline of a strategy for improvement in those information and knowledge-intensive areas that have an impact on energy-efficient production and manufacturing productivity of SMcorp

Part two. Engaging the right people in identifying required information and knowledge resources

The participants in this stage of IPPS that creates IPPS team are as follows:

- Research group
  - The researcher
  - IKT expert
- Master scheduler
- Production supervisor

In order to understand any delay-related issues potentially affecting the production process on the shop floor the participants identified two areas of concern:

- The reasons of delays, and also
- The interaction between production scheduling staff and other functions of SMcorp

It was agreed that to do this project, the researcher would use data already available on the SMcorp electronic data storage and study input from production scheduling staff in their interaction with other functions.

This was followed by outlining the data analysis that is as follows:

The data to be analysed have a qualitative nature and therefore the methodology that would lead the researcher throughout their analysis can be outlined as follows:

In the analysis the researcher attempts were as follow:

1. Key information-intensive areas: Identify from the process provided by SMcorp key areas that are dependent on information and knowledge, e.g. machine operation, inventory etc.
2. Root causes: Identify from the data available a set of delay-related problems that causes may be related to one or more of the key information-intensive areas identified above
3. Document review: Review documents related to the set of delay-related problems in order to extract for each problem those issues that can be related directly or indirectly, to the request or supply of information resources (i.e. to the key information-intensive areas).

- A set of delay-related problems would be selected based on parameters to be agreed with the SMcorp supervisor (IKT expert) and the academic supervisor (Manufacturing research expert).
- Documents to be reviewed in relation to each delay-related problem may include forms of communication between SMcorp and its functions, such as learning and development, trainings etc.

4. Key issues (per individual problem): Extract key issues emerging from each individual delay-related problem
5. Key issues (cross-errors): Look for patterns or recurring issues, i.e. appearing in more than one issue

Phase 1 – Stage 2. Project preparation

Part one. Selecting individuals with problem-centred knowledge for IPPS

The purpose of the collaboration helps identifying the potential functions and selecting representatives from those functions who have problem-centred knowledge and can contribute to the process of IPPS. Therefore, in running EC-FIKT there are no particular restriction on the professional background of individual participants. They may have complementary or even contradictory views of the domain. Archer and Cameron (2012) emphasise that IPPS leadership assist gaining value from these. Schwarz (2002) remarks that skilful leader(s) can turn these differences into learning objects that can clarify the problem domain. Therefore, such differences have the potential benefits for later stages of EC-FIKT.

In the SMcorp project, it was important to investigate issues related to information and knowledge transfer from data available in order to select the right functions for the collaboration.

The issues related to information and knowledge resources and their transfer that would be sought by analysing the interaction between PS staff and other SMcorp functions include, among many others, the following:

1. Resources which are available within the SMcorp but are not provided to the production scheduling (despite having been requested on occasions) due to lack of knowledge by the staff in other functions or on the basis of existing SMcorp policies

2. Resources that are provided to the production scheduling (whether or not these have been requested) but are not necessarily correct, relevant or accurate, or are not based on SMcorp standards

Nonaka *et al.* (2001) remark that experimental knowledge represents tacit knowledge that is shared among internal functions including data-dependent functions. Therefore, two of the very important sources of experimental knowledge about delay-related problems on the shop floor are PS staff's experience and other functions, such as process planning and inventory, experience of designing or handling the process. Consequently, in order to understand these issues, the following data would be investigated:

1. Delay-related data: The intention is to understand the main reasons leading to delays on the shop floor in order to analyse which of these maybe related to lack or inefficient information and knowledge transfer
2. PS staff interview: The intention here is to conduct interviews with production scheduling experts and analyse the factors influencing the quality of the interaction between production scheduling functions and other functions of SMcorp

After identifying the above discourse, the individuals selected for this IPPS were as follows:

- The researcher
- Quality control analyst – IKT research expert
- Master scheduler
- Experts from SMcorp different functions of production on the shop floor
    - Inventory officers
    - Machine operators
    - Managers
    - Supervisors
    - Technicians

Part two. Inviting the selected individuals to engage in IPPS

- The researcher

  This collaboration was part of the researcher's PhD and the researcher was willing to learn from practice during this field research and contribute to the success of the project

- The IKT research expert

  This collaboration was part of IKT research expert's research work at SMcorp

- SMcorp representative – Production manager

  SMcorp representative was highly encouraged to identify the factors influencing manufacturing productivity of SMcorp, therefore, he was willing to engage in IPPS as part of his work in business improvement

- Experts from production-related functions of SMcorp

  The SMcorp representative selected a group of expert from different functions of SMcorp who have information and knowledge related to issues at the shop floor. All of these participants agreed on the benefits of IPPS approach that can address energy savaging and manufacturing productivity

Part three. Planning the conceptual and structural requirements

Peschl and Fundneider (2014) explain that the structure, architecture and design, comprises all the elements in collaboration environment and its context. They emphasise that designing facilitative environment to support social interaction, people-based information and knowledge transfer with the aim of problem-solving is difficult. They remark that poor architecture supports ineffective collaboration rather than effective problem-solving. However, the conceptual structure had a prior role in IPPS project with SMcorp. During this field research, most of the meetings with the SMcorp representative and other experts were one-to-one meetings and did not require any specific structural arrangement. The meetings that included more than two people, or the ones which needed projectile and screen could be arranged on the same day of the meeting and did not require any particular preparation. However, conducting circle meeting was never neglected in any of these group meetings and it was maintained throughout the IPPS meetings to facilitate participants' interaction and participation in problem-solving. Pranis (2014) suggests that a group sitting in Circle meetings are considered as equals and this helps them to listen to one another better and better understand each other's concerns and frustrations during the meetings. She explains that circular talks can be used as facilitator connecting the participants. Baldwin and Linnea (2010) emphasise that choosing circle meeting has become an incidental part of many co-

creative innovations and modern group meetings and can be considered as required basic setting of any meeting.

During collecting data about employees' experience within one function, there was no need for preparing the environment for effective IKT meetings for the reason that participants were from one particular function of the SMcorp and ready to contribute to its improvement and better performance, they had very similar problem-centred information and knowledge and they were not concerned about any negative impact of sharing their experience. In the company-wide application of EC-FIKT, however, the conditions are more complicated. To address this challenge, this research used a new description for intra-organisational meetings, *Design-shop.* Burck (2014) emphasises that Design-shop is a facilitated environment within which people who have a key stake in the required change meet and contribute to problem solving. The description of Design-shop will be included in this section.

Siekman (2001) remarks that Matt and Gail Taylor developed the concept of Design-shop in the 1980s to encourage creative collaboration between members of a group beyond the conventional group works. He explains that the Taylor approach supports engagement of diverse groups of functions in solving complex problems through information and knowledge transfer and designing solutions that fosters problem-solving. Burck (2014) explains that the concept of the Design-shop collaboration distinguishes it from the traditional workshops for number of reasons that are as follows:

- In this type of collaboration, the focus is on meaningful problem-related conversation between the participants. It facilitates parallel work of small groups to enhance the chance of better understanding of the participants' perspective

- One of the characteristics of Design-shop is that it is a focused collaboration approach and maintains collaborative experience

- Design-shop provides iterative and non-linear process that supports better understanding of the root causes of the problem through sharing problem-centred experiences in advance to creating the final designs of the solutions

- Developing a collective vision that emerges in non-linear collaboration is the result of skilful facilitation of feedback loop that feeds back on the development of the components of final solution

- Shared experience advanced during the Design-shop collaboration facilitates creating new patterns of thought and action and it integrates individual's characteristics into a collective identity

Burck (2014) emphasise the effort of leader in Design-shop collaboration is essential and has direct influence on the success or failure of the collaboration. Gavrilova and Andreeva (2012) describe that level of involvement of the leader and participants and the type of interaction between them in three categories that are as follows:

1. Active involvement and interaction method. In this method the leader leads the collaboration through asking questions with the aim of knowledge elicitation from participants
2. Passive involvement and interaction method. In this method the leader facilitates engagement of participants in leading the collaboration, therefore, the role of the leader can be just to listen or observe and then analyse
3. Equal involvement and interaction method

High amount of uncertainty adds to the limitations of collaboration between independent functions, therefore, trust is a key factor for investigating variation in the outcome of intra-organisational collaboration (Bstieler *et al.*, 2017). Therefore, for successful collaboration, *trust* is essential. In particular, in intra-organisational collaboration, trust has fundamental role. Moreover, Carlile (2004) emphasises that lack of common interest among the participants creates pragmatic boundaries and dealing with conflicting interests requires significant practical efforts.

Bstieler *et al.* (2017) describe the evaluation of the success of Design-shop followed by problem-solving in three categories which support the development of mutual trust between the participants that are as follows:

1. Demographic similarity. Demographic characteristics include age, gender and background. In collaborative problem-solving context, demographic similarities in levels of skills, experience and problem-centred information and knowledge plays an important role in the success of collaboration. Tsui *et al.* (2002) remark that, demographic similarities in the levels of experience and knowledge can have positive initial influence on trust.

2. Reciprocal communication. Through working together and building mutual perceptions, participants gain trust. This is more feasible through two-way communication (Bstieler and Hemmert, 2008) where the collaborators develop understanding about trustworthiness of each other which promotes willingness to engage in information and knowledge transfer and collaborative problem-solving (Ferrin *et al.*, 2008)
3. Decision process similarity. Decision process can be described as a combination of the degree to which participants share similar decision making styles that leads to trust and improves the conduct of collaboration sessions. Levin and Cross (2004) explains that participants reveal greater trust in collaborations where they have similar goals and decision process. Moreover, common understanding of collective goals and ways of acting provides a reliable foundation for trust.

Vanneste *et al.* (2014) remark that trust can depend on the length of the relationship. Schilke, and Cook (2013) explain that the development of trust over time can be explained as relationship maturity. Bstieler *et al.* (2017) emphasise that relationship maturity has great positive influence on the effectiveness of the three categories discussed above followed by improving the mutual trust between participants in collaboration session. This relationship is shown in Figure 4-4.

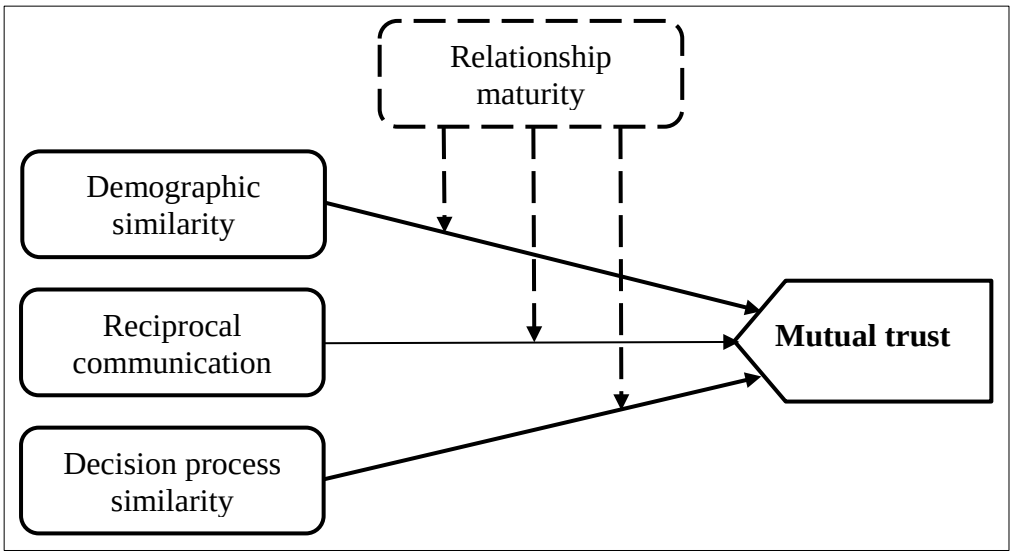

Figure 4-4. The factors influencing mutual trust in collaborations (Bstieler *et al.*, 2017)

In addition to developing trust among participants, pragmatic boundaries are the most difficult and complex to address in Design-shop activity due to the differences of interest that exist between individual participants or different groups of participants. Carlile (2004) suggests that both object/model and maps are appropriate boundary objects for this context. This is because the development and use of maps allow people to better understand and appreciate the differences of interest that exist, while the use of objects/models can provide a resource which not only allows people to develop a sense of shared interests and common endeavour, but which also allows people to transform their experience and knowledge to achieve a collective goal. Thus, with the spanning of pragmatic boundaries, the primary knowledge process is one of transformation.

Phase 2. People-based information and knowledge transfer

Phase 2 – Stage 1. Effective communication

Context chart – a network, mapping the interrelationship among the roles and groups (Miles *et al.*, 2014) - for individuals/functions that engaged in the questionnaire and intensive collaboration Design-shop sessions is shown in Figure 4-5.

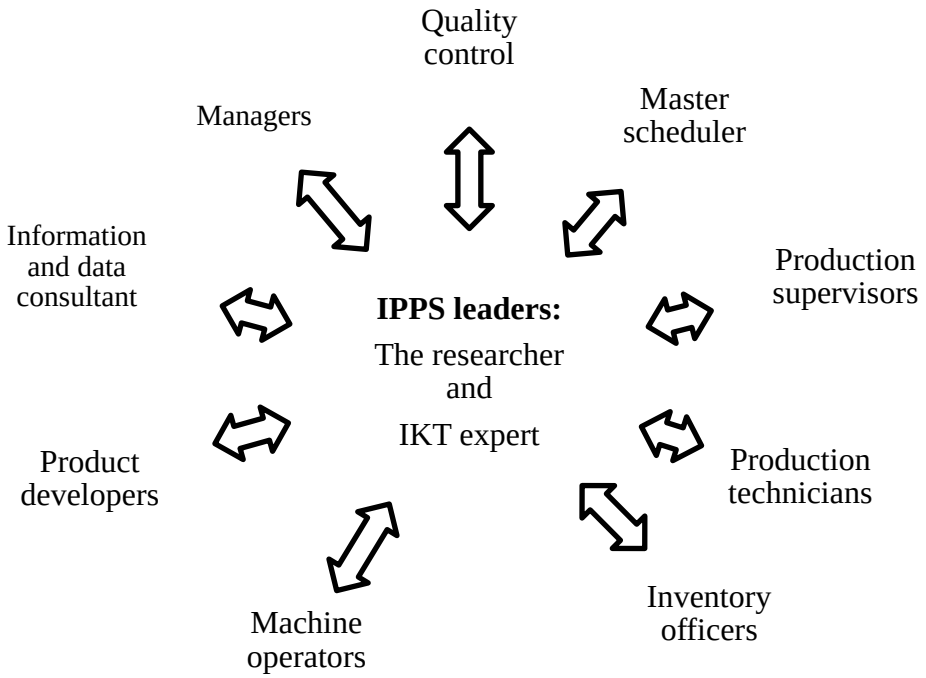

Figure 4-5. Context chart for individuals/functions participated in the IPPS at SMcorp

Part one. Clarifying the purpose of IPPS with participants

The participants might not have participated in collaborative IKT sessions or might not have clear understanding of the purpose. It is the leader(s) responsibility to prepare an environment that enables participants to engage in sharing their information and experience without being concerned about their knowledge not being valued or misused. Neglecting the significance of this trust among the participants would result in omission of expected value of the collaborative problem-solving. To build this sense of trust, the leader(s) should clarify the purpose of the collaboration and its benefits for the domain that includes each and all of the functions of the concerned manufacturing company.

The purpose of collaboration was to improve the SMcorp and the researcher interpretation of the root causes of delays on the shop floor. The purpose was reviewed at the start of all the collaboration meetings with SMcorp representative and experts. It was easy to accept the purpose of IPPS for them. In particular, because they had some assumptions but the specific reasons of delays were not really clear and they were eager to identify the causes of it.

Part two. Engaging participants in sharing their perceptions of the problem

This stage of EC-FIKT assists IPPS leader(s) and participants in hearing each other while the participants are invited to freely discuss their perception of the problem including their concerns without being interrupted by other participants. The leader should prepare an environment in which each of the participants have the opportunity to express their problem-centred knowledge without being interrupted with other participants who might have different or complete opposite assumption of the problem. It is the leader's responsibility to ensure that each participant's perception of the problem and area of concern are valued. Moreover, collecting different perspectives helps the leader and other participants to better understand the areas of concern for different stakeholder groups.

Facilitative leadership prepares the interface between the participants and ensures the transparency of the discussions around the factors affecting the problem. This approach assists adjusting conflicting assumptions among the participants and creating valuable insight into the problem that results in developing matured understanding of the challenge in the domain. Schwarz (2002) remarks that conflict is inevitable part of collaborative group; however, skilled leader can turn this conflict into effective group collaboration. He explains

that skilful leader turns conflict into learning objects that can contribute to better understanding of the problem domain.

In order to understand different functions' perception of the problem (delays on the shop floor), the researched conducted a questionnaire distributed to 20 experts from functions of the SMcorp. A questionnaire was distributed to twenty employees. Except the four of the questionnaires that were incomplete, sixteen questionnaires were used in this stage of effective communication through facilitated information and knowledge transfer. Table 4-1 shows the attributes of the participants, subsuming gender, work position, age, years of experience, type of different manufacturing systems and layouts. In terms of position, 2(12.5%) were inventory officers, 7(43.8%) were machine operators, 1(6.3%) was either a manager, quality assurance officer, Technician or a welder, while 3(18.8%) were supervisors. The high response rate among the machine operators indicate that this work position champions manufacturing productivity and process improvement through proper planning.

In terms of gender, 14(87.5%) were male while 2(12.5%) were female. This would be anticipated as it toes with the distribution of males in the manufacturing sector. Compared to females, more male workers are employed in manufacturing engineering companies.

On age, 2(12.5%) were in the age bracket of 30 years and below, 7(43.8%) between 31 and 40, 6(37.5%), while 1 was between 51-60 years old.

Years of experience showed that 7(43.8%) had 11-15 years of experience, 5(31.3%) had 16-20 years while 4(25.0%) had 21 and above years of experience. The years of experience influence the planning decisions on improving manufacturing productivity.

It also showed that 4(25.0%) were involved in jobbing production while 12(75.0%) were into mass production.

With respect to plant layout, 8(50.0%) uses process or functional layout, 4(25.0%) uses either product/line layout or combination/group layout. Plant layout variable was investigated since it largely influences productivity improvement measures such as workforce productivity.

Table 4-1. Demographic distribution of participants

Variables	**Categories**	**Number of participants**	**%**
Position	Inventory Officer	2	12.5
	Machine Operator	7	43.8

Table 4-1. Demographic distribution of participants

Variables	Categories	Number of participants	%
	Manager	1	6.3
	Quality Assurance Officer	1	6.3
	Supervisor	3	18.8
	Technician	1	6.3
	Welder	1	6.3
Gender	Male	14	87.5
	Female	2	12.5
Age (years)	30 and Below	2	12.5
	31-40	7	43.8
	41-50	6	37.5
	51-60	1	6.3
Years of experience	11-15	7	43.8
	16-20	5	31.3
	21 and above	4	25.0
	Product or line layout	4	25.0
	Combination or group layout	4	25.0

The researcher created four key areas that can have positive impact on improving manufacturing productivity that are as follows:

1. Production planning and scheduling
2. Improving productivity in production
3. Optimisation of the process plant layout
4. Controlling and maintaining the quality of inputs and outputs

There researcher also assigned sub-categories to these areas before distributing them in form of questionnaire to the selected experts. Table 4-2 shows the mean and standard deviation on improving manufacturing productivity through improved manufacturing process planning across engineering organization by production planning and scheduling (M=4.63, SD=0.24). It shows that the highest mean production planning and scheduling were that there should be an identification of the purpose of the processes which may include the name, quantity and quality of the product to be produced (M=4.75, SD=0.45), specifications are needed to make each operation conform to the principles of interchangeable manufacture and quality control (M=4.75, SD=0.45) and there is need for specification of performance expected from each operation relative of the capacity of the production equipment (M=4.75, SD=0.45). These

were followed by the mean that there should be list of operations making up the process, an enumeration of the operations to show their sequence and designation of the place where each operation is performed (M=4.69, SD=0.48) and that all operations required in the manufacture of a product should be combined and put in proper and best sequence (M=4.69, SD=0.48). The least means were that there is need for specification of performance expected from each operation, in the form of the estimated or standard cycle time per piece and output expected in a certain length of time (M=4.50, SD=0.52) and there should be provision for improvement on the specification; all specification must be clear and explicit (M=4.50, SD=0.63)

Table 4-2. The impact of improved production planning and scheduling on manufacturing productivity

		Number of participants=16	
	Production Planning and Scheduling	**Mean**	**Standard Deviation**
1	There should be an identification of the purpose of the processes which may include the name, quantity and quality of the product to be produced.	4.75	0.45
2	There should be list of operations making up the process, an enumeration of the operations to show their sequence and designation of the place where each operation is performed	4.69	0.48
3	Specifications are needed to make each operation conform to the principles of interchangeable manufacture and quality control	4.75	0.45
4	There should be specification of the methods, machines, tools and equipment to produce the required quantity and quality of the products.	4.56	0.51
5	There should be specification of the methods, machines, tools and equipment to produce the required products at the lowest cost.	4.63	0.50
6	There is need for specification of performance expected from each operation, in the form of the estimated or standard cycle time per piece and output expected in a certain length of time.	4.50	0.52
7	There is need for specification of performance expected from each operation relative of the capacity of the production equipment	4.75	0.45
8	Requirements and conditions of the processes which may include the specifications of the finished products, the size and shapes are necessary.	4.56	0.51
9	Requirements and conditions of the processes	4.63	0.50

	which may include the specifications of other properties of the raw materials and the quality to be produced is necessary.		
10	There should be provision for improvement on the specification; all specification must be clear and explicit	4.50	0.63
11	The most practical and economical manufacturing methods must be determined	4.63	0.50
12	The selection of the correct equipment is a necessity	4.63	0.50
13	All operations required in the manufacture of a product should be combined and put in proper and best sequence.	4.69	0.48
14	Plant layout should be such that eliminates machine idle time in relation to inputs and outputs of production	4.56	0.51
	Grand mean	**4.63**	**0.24**

Table 4-3 shows the mean and standard deviation on improving manufacturing productivity through improved manufacturing process planning across engineering organization by improving productivity in production (M=4.50, SD=0.31). The highest mean improvement was that work-study; The best way of doing a job and the time taken to do it efficiently is necessity (M=4.69, SD=0.48) and the importance of human factor in production: It has been increasingly realized that the man behind the machine is more important than the machine itself as productivity will not be improved if the man is not efficient (M=4.69< SD=0.60). These were followed by a good plant layout which may include material handling will result in lower cost of production and higher productivity (M=4.56, SD=0.51). The least was that every company who believes in development and higher productivity should have a strong research and development (R&D) department (M=4.31, SD=0.60).

Table 4-3. The impact of improving productivity in production on manufacturing productivity

		Number of participants=16	
	Improving Productivity in production	**Mean**	**Standard Deviation**
1	Work-study; The best way of doing a job and the time taken to do it efficiently is necessity	4.69	0.48
2	Work-study; Breaking down the job into its various elements and ensuring that all workers engaged in the job are trained to do it the best way	4.44	0.51
3	A good design of production which helps in the economical and convenient manufacturing (designing for production) will minimise scrap(waste) and reduce the cost of production	4.50	0.52

Table 4-3. The impact of improving productivity in production on manufacturing productivity

		Number of participants=16	
	Improving Productivity in production	**Mean**	**Standard Deviation**
4	Cost of production can be reduced by efficient and economical utilization of all the inputs resources, eliminating all types of wastages.	4.50	0.52
5	A good plant layout which may include material handling will result in lower cost of production and higher productivity.	4.56	0.51
6	Market research should be carried out to determine the actual requirement of the product, assess popularity of the company's products, identify and tap new markets.	4.50	0.63
7	Every company who believes in development and higher productivity should have a strong research and development (R&D) department.	4.31	0.60
8	Quality control functions should include inspection of incoming and outgoing materials, parts and products, inspection of work in progress and prevention of poor quality by timely warnings.	4.50	0.52
9	Inventory control is the life blood of a production system that endeavours to achieve a balance between two little inventory and two much inventory.	4.44	0.51
10	Automation of machines so that it can work for a relatively long time without human intervention should be encouraged.	4.38	0.62
11	The importance of human factor in production: It has been increasingly realised that the man behind the machine is more important than the machine itself as productivity will not be improved if the man is not efficient.	4.69	0.60
	Grand mean	**4.50**	**0.31**

Table 4-4 shows the mean and standard deviation on improving manufacturing productivity through improved manufacturing process planning across engineering organization by Optimization of the process plant layout (M=4.62, SD=0.27). The highest mean optimization of process layout was that the layout should provide adequate safety, healthy and comfortable working condition to all employees (M=4.81, SD=0.40). This was followed by the layout should ensure maintenance of equipment and control of production is easy (M=4.75, SD=0.45) and the layout should be such that supervision is easy, simple and effective (M=4.69, SD=0.48). The least mean was the all process layout should have provisions for future expansion of the plant (M=4.44, SD=0.51).

Table 4-4. The impact of optimisation of process plant layout on manufacturing productivity

		Number of participants=16	
	Optimisation of the process plant layout	**Mean**	**Standard Deviation**
1	The entire space of the plant/equipment layout should be economically and effectively utilized	4.56	0.63
2	The investment in equipment should be kept at the barest minimum	4.63	0.50
3	The handling and transportation of materials should be minimum	4.56	0.51
4	The flow of materials should be smooth and rapid	4.56	0.51
5	The layout should be such that supervision is easy, simple and effective.	4.69	0.48
6	The utilization of men and machines should be optimum	4.56	0.51
7	The layout should ensure maintenance of equipment and control of production is easy.	4.75	0.45
8	The layout should provide adequate safety, healthy and comfortable working condition to all employees.	4.81	0.40
9	The layout should make for a flexibility of rearrangement of production flow process	4.63	0.50
10	All process layout should have provisions for future expansion of the plant.	4.44	0.51
	Grand mean	**4.62**	**0.27**

Table 4-5 shows the mean and standard deviation on improving manufacturing productivity through improved manufacturing process planning across engineering organization by controlling and maintaining the quality of inputs and outputs (M=3.35, SD=0.29. The highest mean control and maintenance on quality of input and output was that quality of your company's product should at all times conform with international acceptable standard (M=4.75, SD=0.45). This was followed by generation of outputs should be geared towards efficient utilization of inputs (M=4.56, SD=0.63) and the right control mechanism should be put in place to ensure high quality of products (M=4.56, SD=0.51). The least was that the inputs of production should be regulated at all times (M=4.19, SD=0.75).

Table 4-5. The impact of Controlling and Maintaining the quality of inputs and outputs on manufacturing productivity

		Number of participants=16	
	Controlling and Maintaining the quality of inputs and outputs	**Mean**	**Standard Deviation**
1	The inputs of production should be regulated at all	4.19	0.75

Table 4-5. The impact of Controlling and Maintaining the quality of inputs and outputs on manufacturing productivity

		Number of participants=16	
	Controlling and Maintaining the quality of inputs and outputs	**Mean**	**Standard Deviation**
	times.		
2	Inputs should be continuous regardless of the output obtained	1.94	0.77
3	Generation of outputs should be geared towards efficient utilisation of inputs	4.56	0.63
4	Much emphases should not be placed by the company on the quality of turned out products	1.81	0.75
5	Quality of your company's product should at all times conform with international acceptable standard	4.75	0.45
6	Detected non-conforming products should still be accepted by the quality control personnel to reduce wastages.	2.31	0.87
7	The right control mechanism should be put in place to ensure high quality of products	4.56	0.51
8	Less effort should be made to minimize wastage of inputs.	1.69	0.60
9	Economic order quantity is optional in terms of avoiding over inventory of input resources.	4.31	0.95
	Grand mean	**3.35**	**0.29**

The evaluation method proposed by this research to identify the validity and applicability of new knowledge collected through the questionnaire is shown in Figure 4-6.

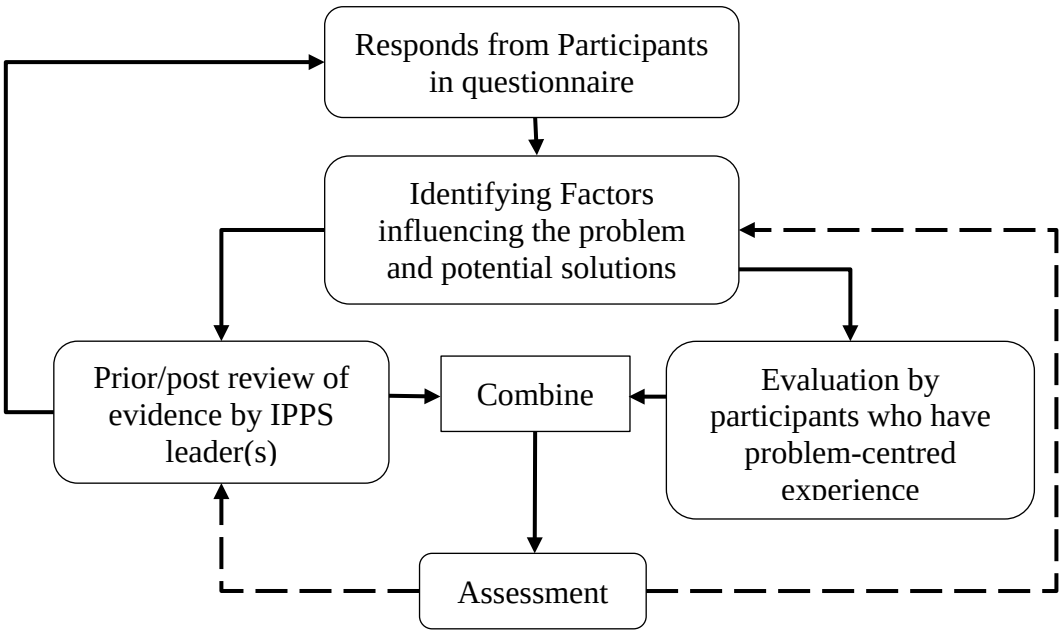

Figure 4-6. Evaluating the knowledge created collected through questionnaire

Part three. Creating credible problem resolution at the start of Design-shop sessions

Creating credible problem resolution without encountering significant disagreement between functions requires skilled leadership that addresses the complexities associated with limited sense of shared characteristics and common knowledge. Schwarz (2002) emphasises that considering the group's concern during developing problem resolution, increases the effectiveness of the collaboration.

Minimum delay on shop floor is normally achieved when related functions receive optimal communication between required functions without further concerns involved. The IPPS team agreed that the lack of such communication needs to be addressed by the EC-FIKT.

It was important to create credible problem resolution that covers the wide range of factors that have many different influences on lack of efficient communication between functions. This was facilitated through engaging the participants in developing models that illustrated the relationship between those factors and their influences. These models were reproduced in Microsoft Office format to retain and easily distribute a clearer version for participants and this research. A sample of this format is shown in Figure 4-7.

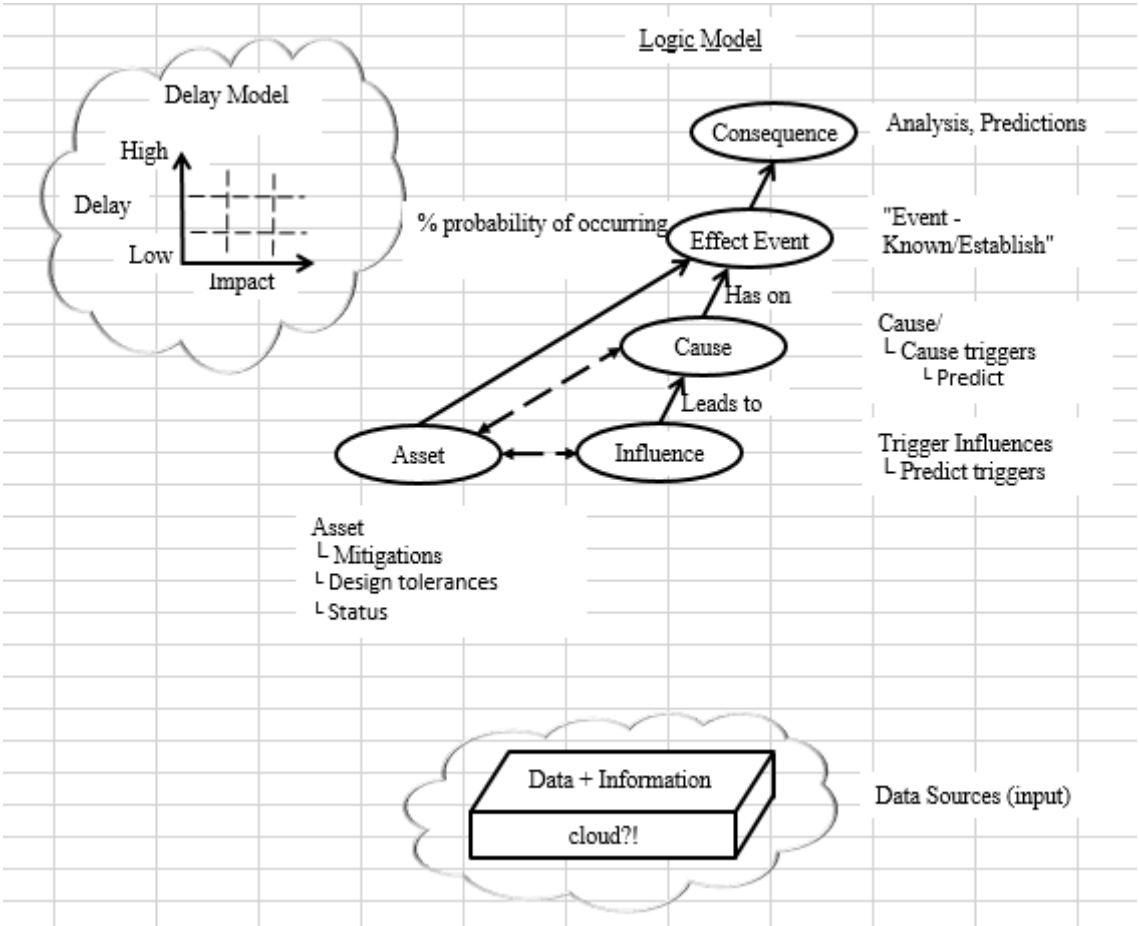

Figure 4-7. Process of creating credible problem resolution by participants

Part four. Engaging the participants in problem-solving

During the Design-shop sessions, participants were divided into four groups that included individuals from different functions or different positions to learn more about available data, information or experience within each functions.

Group one stated ensuring that quality inputs (raw materials) are used with the right manufacturing processes. Group two stated ensuring that both inputs and outputs are checked for quality conformity, Group 3 stated employing quality raw materials and Group four stated the use of good raw materials. This part of the discussion identified the first issue related to delay on the shop floor that is as follows:

- Delay 1: Quality related issues
  - Quality of material before, during and after production
  - Quality of raw material

- The process of checking the quality of raw material

The participants reported about key measures in place to minimize wastages of raw materials. Group one indicated that the company minimise raw material wastage by ensuring that the right machines, materials and manpower are utilized at all times. Group two indicated that the company minimise raw material wastage by ensuring that the inputs are properly measured. Group three indicated that the company minimize raw material wastage by following the required measurement of inputs and specification. Group four indicated that the company minimises raw material wastage by ensuring the required quantity of inputs at a time. This part of the discussion identified the second issue related to delay on the shop floor that is as follows:

- Delay 2: Insufficient engagement of machines, material and manpower
  - Inaccurate estimation of required resources
  - Inaccurate measurement of required resources
  - Uncertainty about required quantity of resources at particular time frames

In addition to control mechanisms, the participants provided information on systems in place for detecting non-conforming products in the companies. Group one reported about quality assurance inspection, Group two reported about testing products by quality control personnel, Group three reported about subjecting finished products to non-destructive testing to ascertain the quality produced and Group four reported proper inspection and testing by the quality assurance officer. This part of the discussion identified the third issue related to delay on the shop floor that is as follows:

- Delay 3: Quality assurance inspection
  - Testing products by quality control personnel
  - Non-destructive testing
  - Time required by quality assurance officer

Network model of these issues was created using Bayesian network modelling, by the researcher, and it is illustrated in Figure 4-8.

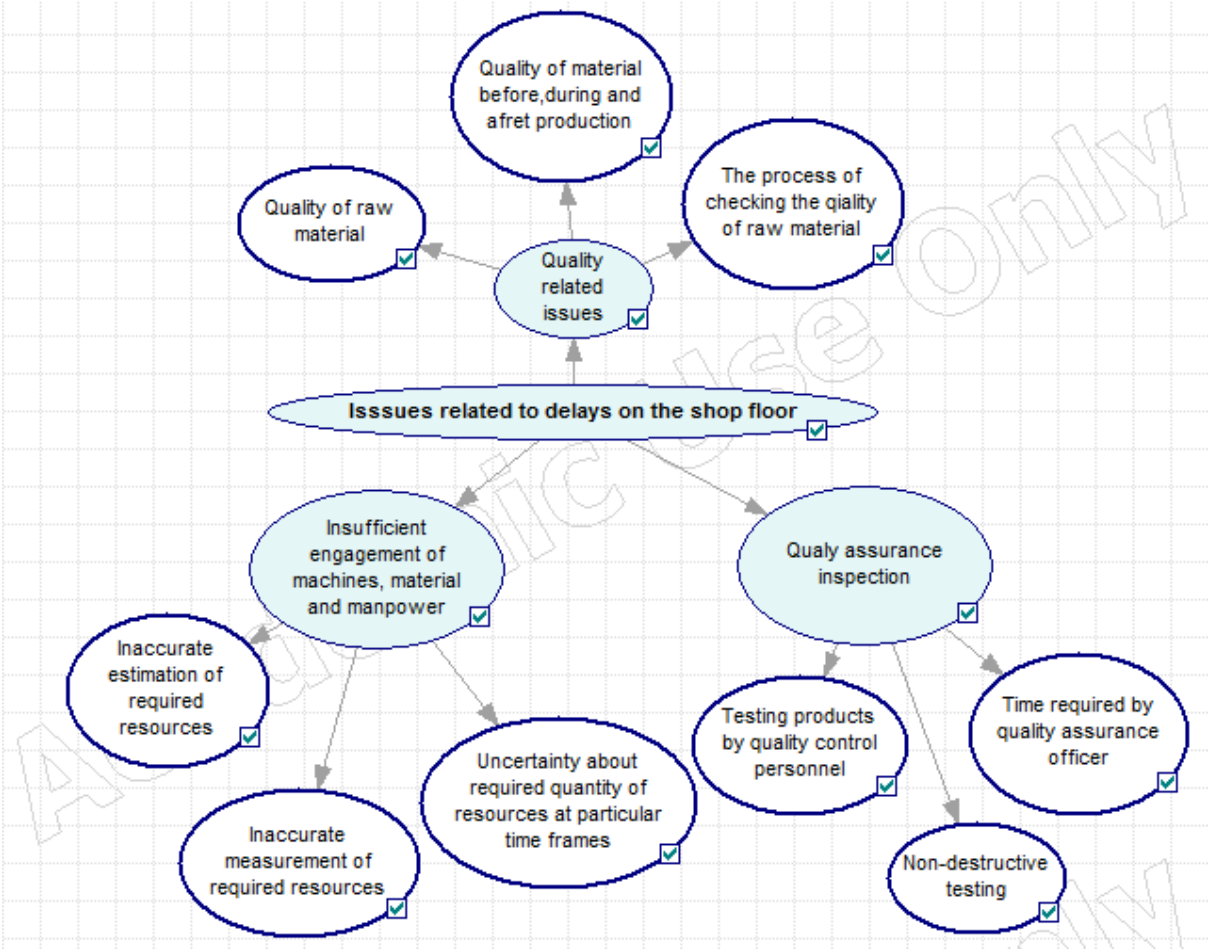

Figure 4-8. Network model of issues related to delays on the shop floor

Phase 2 – Stage 2. Review and reflect

The participants were asked about the main production losses in the manufacturing company. 52% reported equipment failure, 48% reported setups and adjustments, 35% reported reduced speed, 40% reported reduced yield, 28% reported process defects and 20% reported minor stops. To improve the level of manufacturing efficiency and address the above production loss, most participants recommended total production maintenance, which entails system maintenance incorporating manufacturing, planning, performance improvement and maintenance.

Based on 50% of the responses, unplanned stops or equipment failure account for considerable time period in which equipment are scheduled for production, but fail to run due to some errors. The problem is categorised as availability loss. The reasons reported for equipment failure included unplanned maintenance, breakdowns, tooling failure, lack of materials and operators and starvation by upstream as well as downstream equipment.

Network model of these issues was created using Bayesian network modelling, by the researcher, and it is illustrated in Figure 4-9.

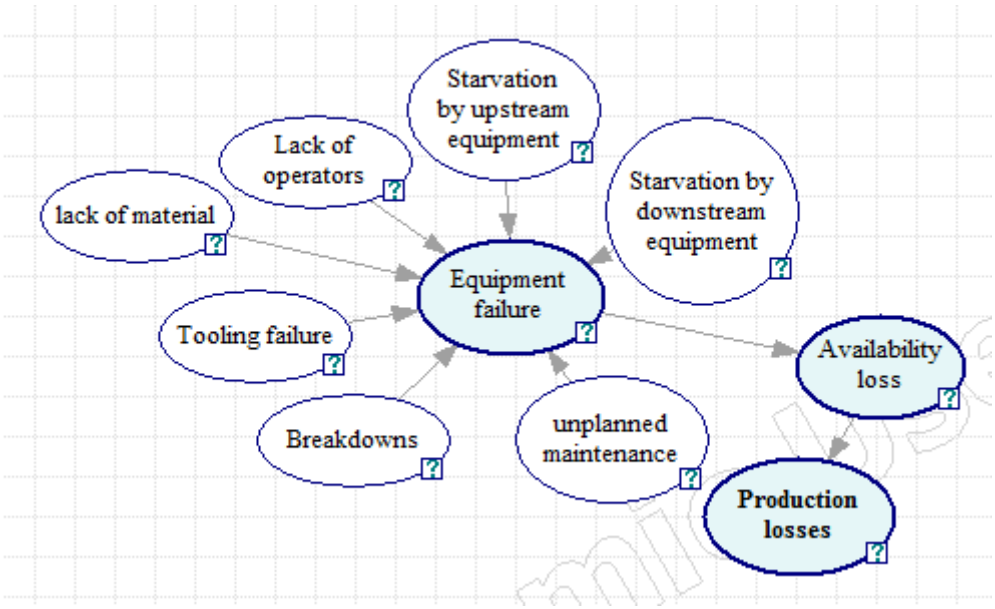

Figure 4-9. Network model of the factors influencing equipment failure with significant effect on availability loss

With respect to setup and adjustment, most participants reported failure to run equipment scheduled for production due to changeover. Being an availability loss, the participants cited major adjustments, tooling adjustments, changeovers and setup. As measures to reduce such loss, most participants suggested quality inspections, planned maintenance, and equipment cleaning. Network model of these issues and suggested solutions were created using Bayesian network modelling, by the researcher, and are illustrated in Figure 4-10 and Figure 4-11.

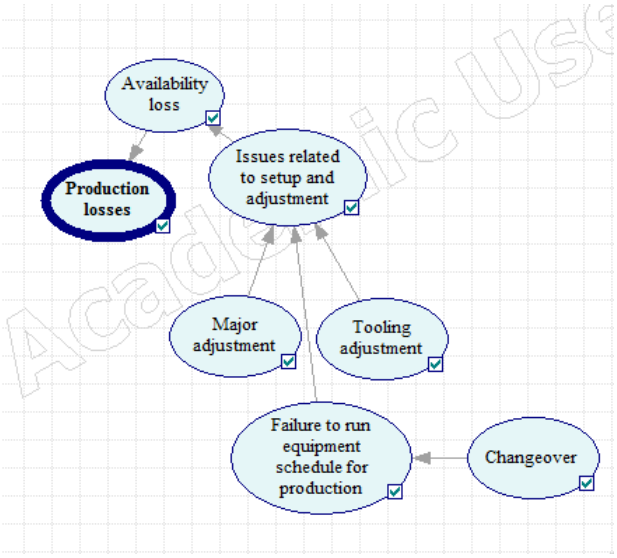

Figure 4-10. Network model of issues related to setup and adjustment with significant effect on availability loss

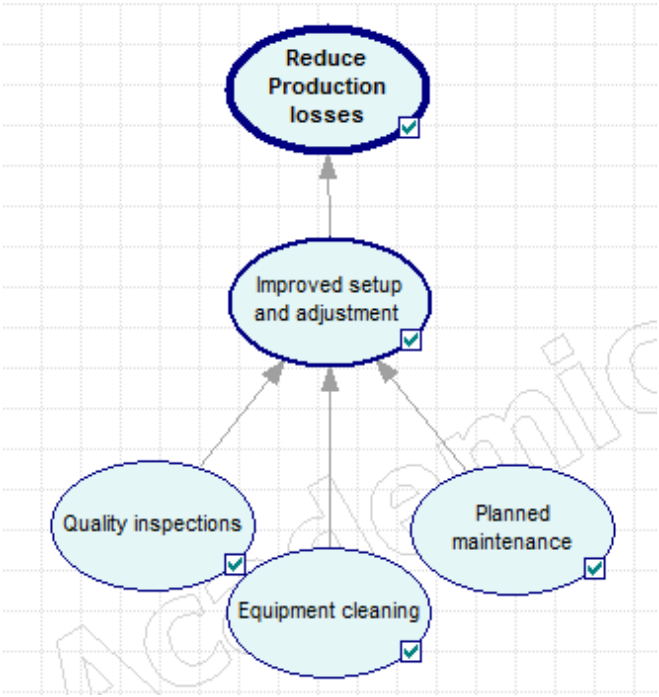

Figure 4-11. Network model of factors influencing improved setup and adjustment

Concerning minor spots and idling, participants described the problem as the situation in which equipment stop operating for some short time (1 or 2 minutes) until operators resolve the problem. Small stops in manufacturing are considered performance loss. 70% reported incorrect settings, congested product flow, material jams, mis-feeds, lack of periodic quick cleaning, equipment design issues and blocked sensors are major reasons for the small stops. To address these problems, 50% of the participants recommended accurately tracking and resolving the small stops, ensuring correct settings before operations and performing periodic quick cleaning. Network model of these issues and suggested solutions were created using Bayesian network modelling, by the researcher, and are illustrated in Figure 4-12 and Figure 4-13.

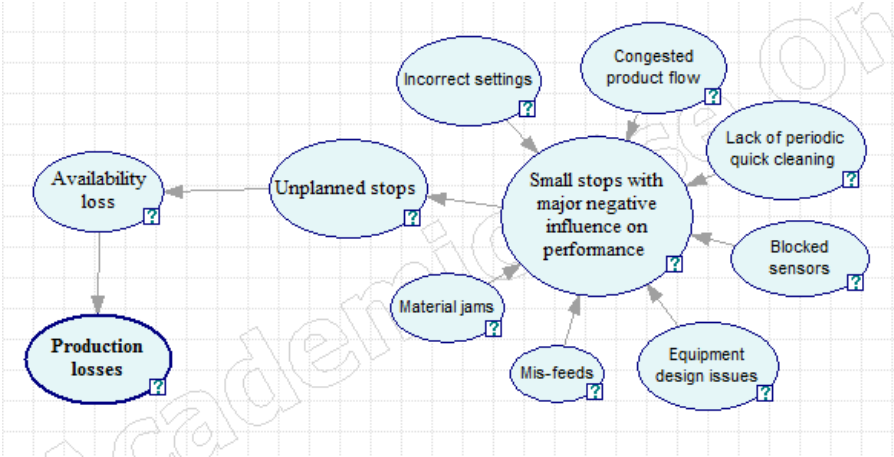

Figure 4-12. Network model of issues with impact on unplanned stops with significant effect on availability loss

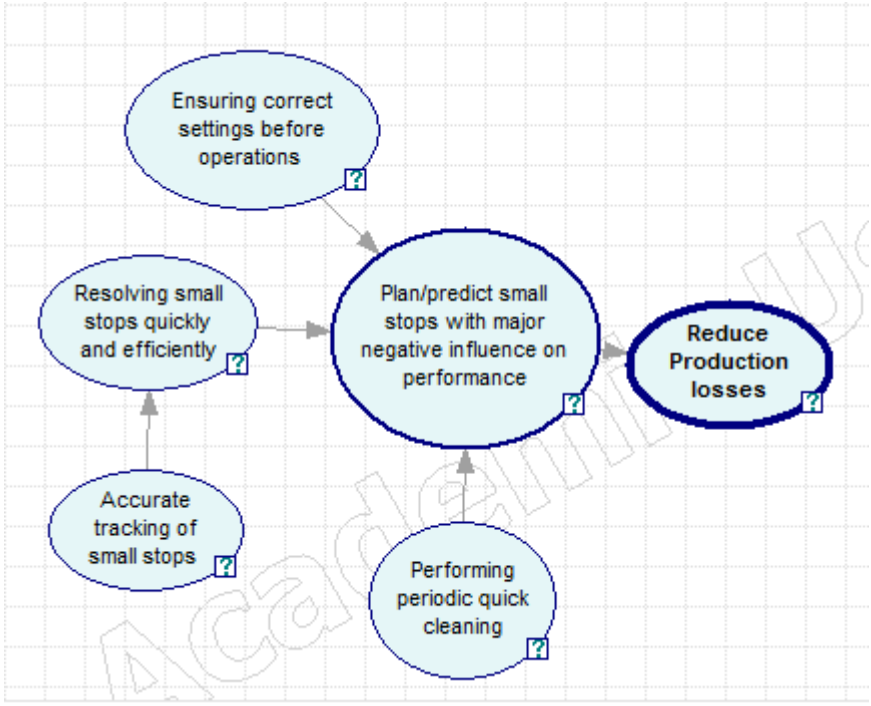

Figure 4-13. Network model of factors assisting small stops

40% of the participants reported reduced speed (slow cycle) as a major production loss, also categorised as performance loss. The equipment, in this case, runs slower compared to ideal cycle time- in theory, the fastest time for possibly manufacturing one part. Of these populace, majority cited poor environmental conditions, substandard material, inexperience of operators, shutdown problems, poor lubrication and use of worn-out or dirty equipment. To address these challenges, most participants recommended using standard manufacturing materials, using clean equipment, using experienced operators and enhancing equipment

lubrication. Network model of these issues and suggested solutions were created using Bayesian network modelling, by the researcher, and are illustrated Figure 4-14 in and Figure 4-15.

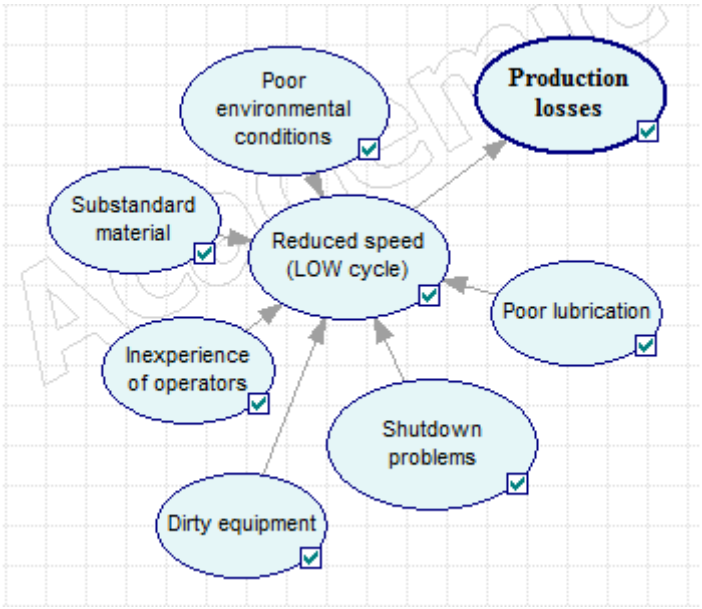

Figure 4-14. Network model of issues that reduced the speed with negative effect on production

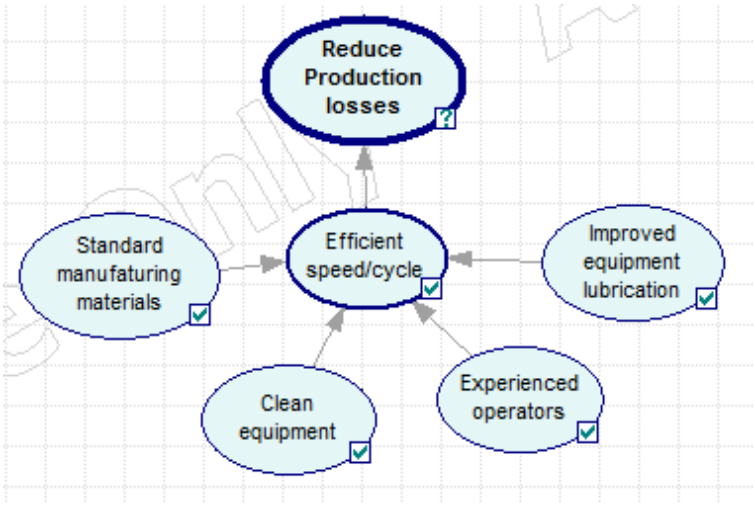

Figure 4-15. Network model of factors assisting efficient cycle time

48% of the participants reported about process defects in production loss, which accounts for the faulty parts produced during stead-state production. This loss is classified as quality loss. While responding to common reasons for quality loss, most participants suggested equipment and or operator handling errors and inaccurate equipment settings. To address these challenges, most of them recommended ensuring correct equipment settings and using

qualified equipment operators and personnel. Network model of these issues and suggested solutions were created using Bayesian network modelling, by the researcher, and are illustrated Figure 4-16 in and Figure 4-17.

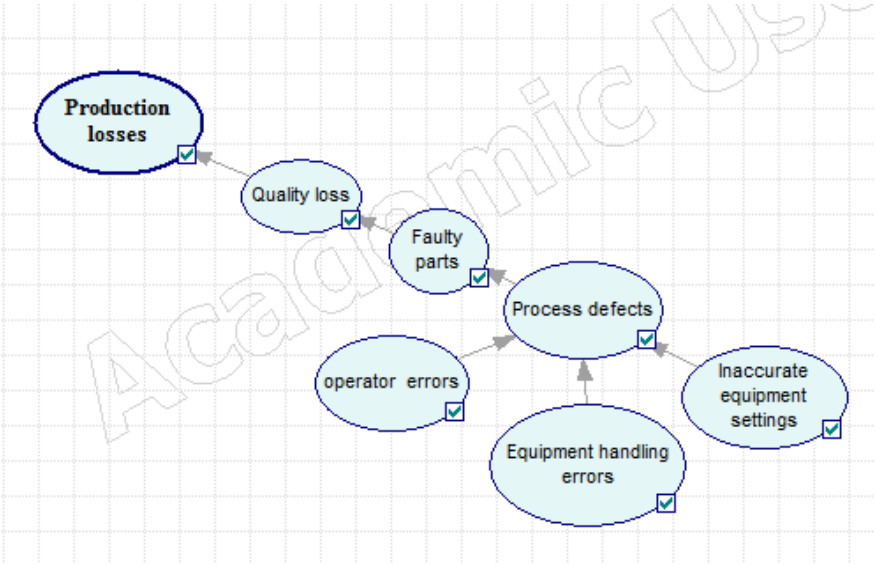

Figure 4-16. Network model of issues with impact on quality loss with significant effect on production loss

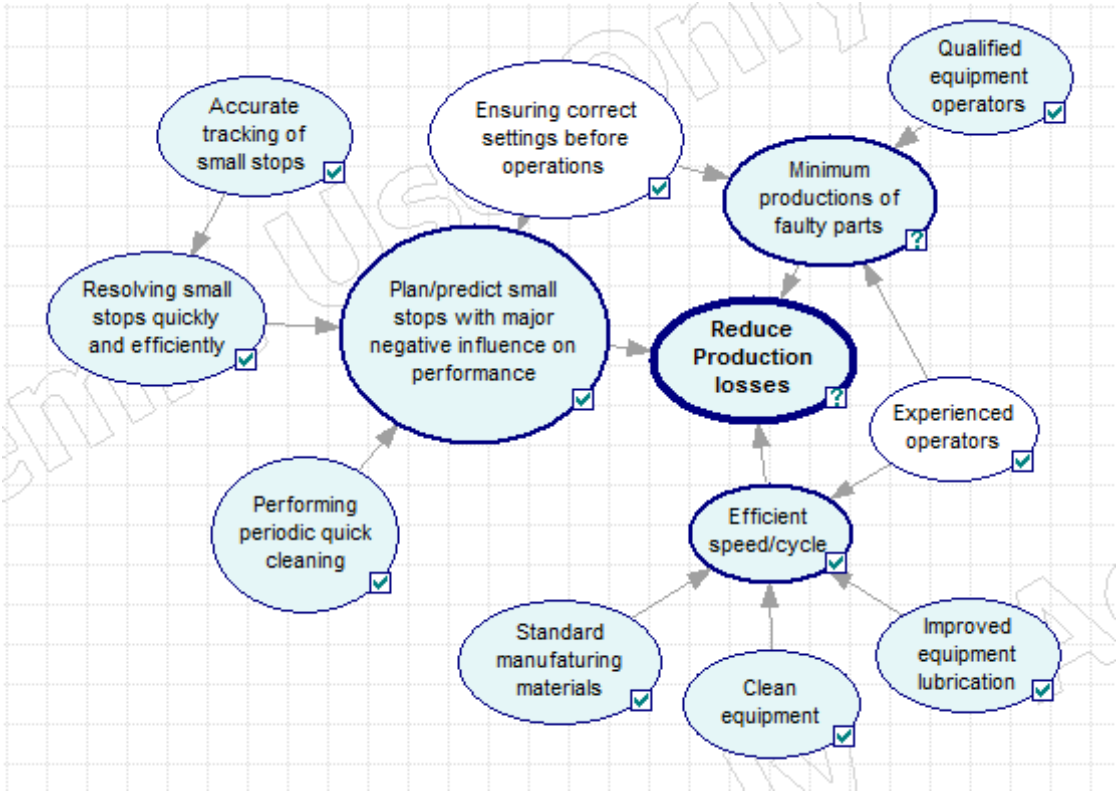

Figure 4-17. Network model of interconnectedness of the factors minimising production losses

40% of the participants also reported about reduced yield as production loss, accounting for the faulty parts manufacturing from the initial stages up to steady-state production phase. Similar to process defects, reduced yield is also categorised as quality loss. The main causes of reduced yield, based on majority of the participants, include equipment constantly creating wastes, equipment requiring warm-up cycles, suboptimal changeovers and incorrect settings while running new parts. To improve the level of manufacturing efficiency, most participants suggested ensuring correct settings, scheduling warm-up cycles for all equipment and tracking all after changeovers. Network models of these issues and suggested solutions were created using Bayesian network modelling, by the researcher, and are illustrated in Figure 4-18 and Figure 4-19.

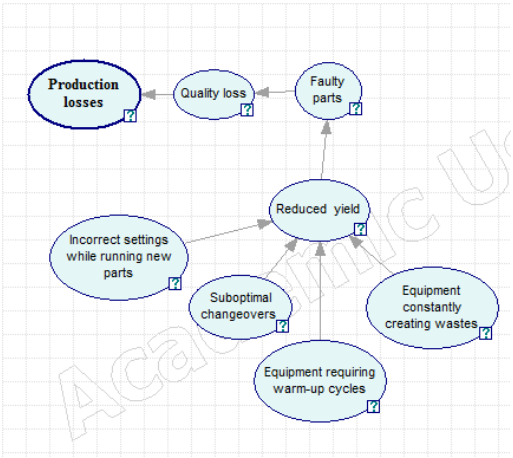

Figure 4-18. Network model of issues with impact on quality loss with significant effect on production loss

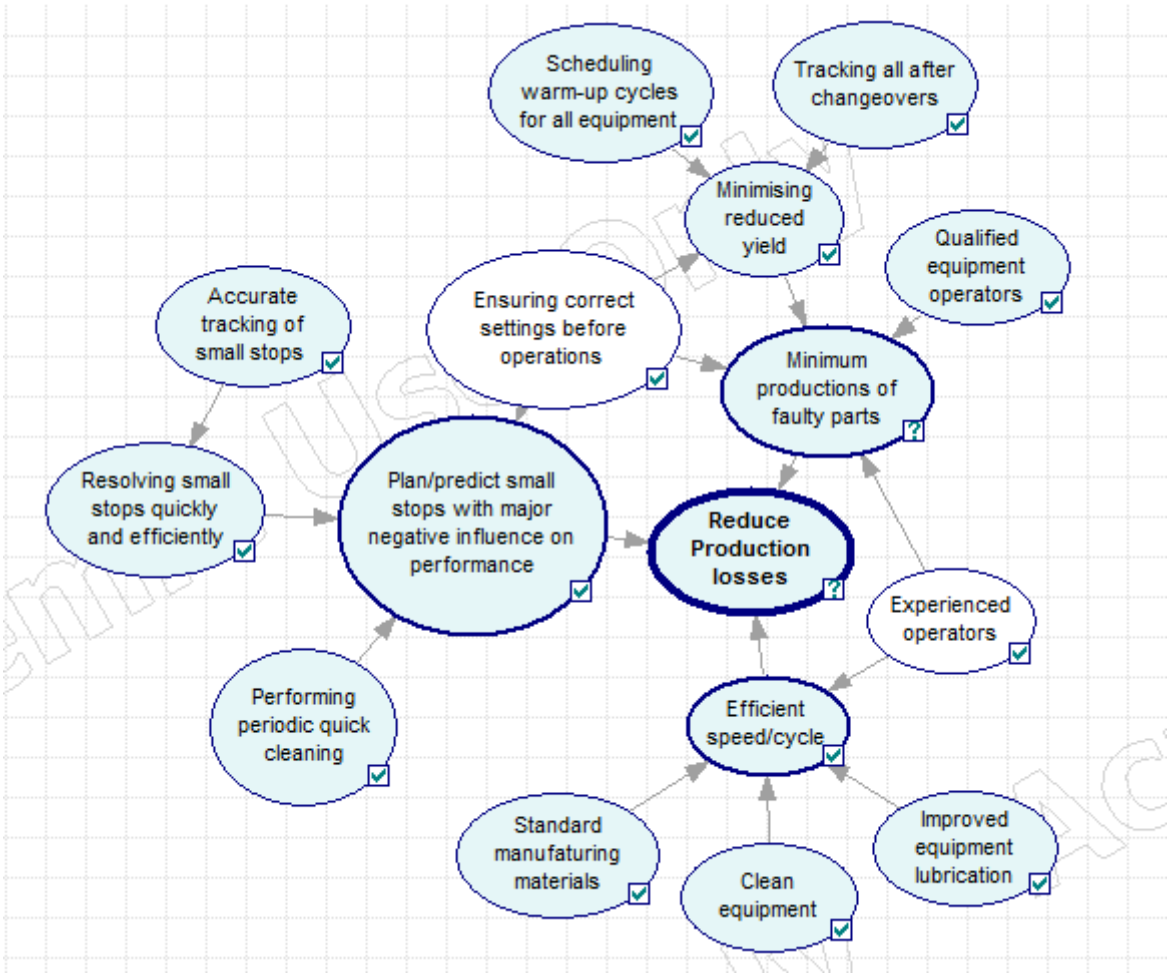

Figure 4-19. Network model of interconnectedness of the factors minimising production losses

Figure 4-20 and Figure 4-21 present the final Bayesian network models produced during this collaboration.

Figure 4-20. The relationship between the issues related to production loss at SMcorp

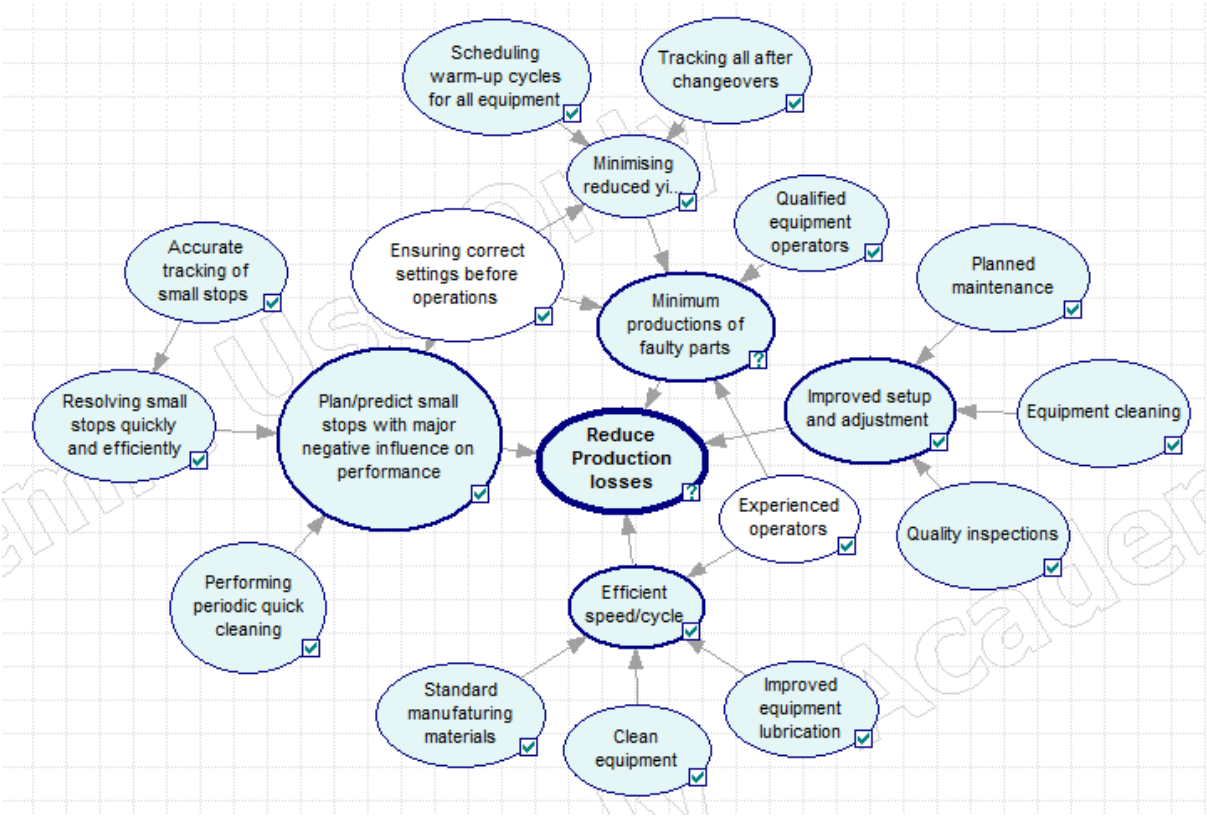

Figure 4-21. The relationship between the factors that can minimise production losses, suggested by the participants

4.2.3. Conceptual framework of the implementation of EC-FIKT

In concluding the description of EC-FIKT method for implementation of IPPS, it is important to mention that specific aspects of this method still require analysis and development. However, the method is being presented with the stability provided by its application in different environments. The conceptual framework that presents the dimensions and relationship between the key stages of the implementation of EC-FIKT method are illustrated in Figure 4-22.

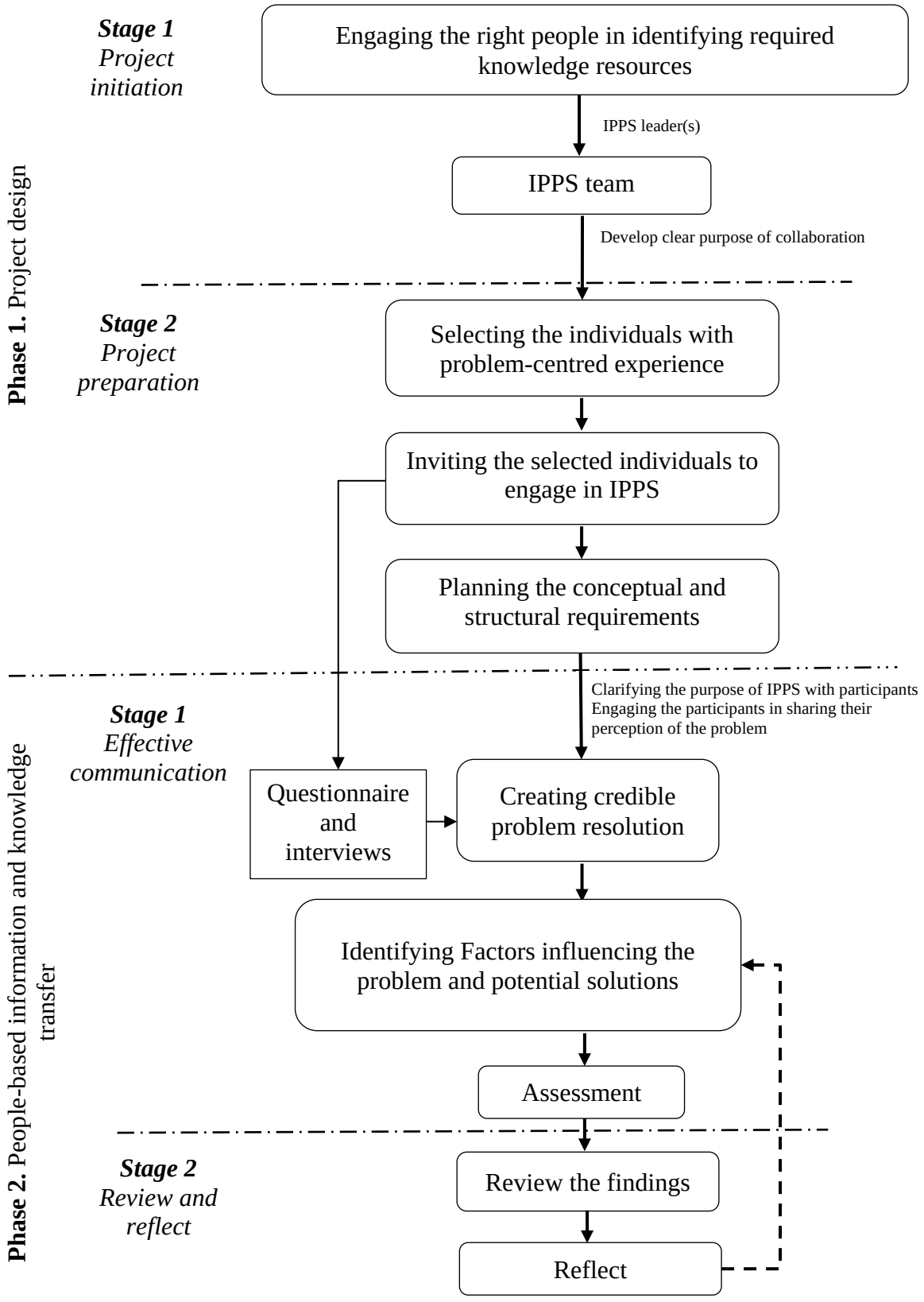

Figure 4-22. The dimensions and relationships between the key stages of the implementation of EC-FIKT method

4.3. Implementing an IPPS project using EC-FIKT method

4.3.1. Introduction

The version of EC-FIKT presented in section 4.2 is the result of the evolution of the method that originated during IPPS project with manufacturing company, SMcorp. Another EC-FIKT exercise during IPPS project with manufacturing company followed the collaboration with SMcorp and has been chosen to illustrate how EC-FKIT can be run in manufacturing companies. It is important to mention that although EC-FIKT had improved significantly during its application, the process described in this section still has particularities that were not encountered in IPPS project with SMcorp. Therefore, despite the success of EC-FIKT, there still exists areas for continued improvement and development and for that reason, further applications are needed for all relevant issues to be fully understood.

Cleaning products Group Ltd (CPG Ltd) supported a research project with the researcher aiming at improving its manufacturing productivity (Cleaning products Group Ltd is a fictitious name, used to preserve confidentiality and anonymity of the manufacturing company and participating individuals). This collaborative research project was the window of opportunity for applying EC-FIKT at this Nigerian manufacturing company located in Rivers State Nigeria.

CPG Ltd manufactures soap. The main manufacturing processes in the company include boiling, salting, strong change, pitching, splitting, mixing, cooling and finishing and milling. The company has both detergent plants and soap plants. The soap plant produces hi-clean soap, laundry tablet soap and vogue toilet soap. The detergent plant produces several brands in different colours and variants, subsuming Sambo, Fax, April, Wash Rite, Flash and Super Deal – commonly used in most Nigerian households. The priority given to quality control in the firm is the core of its longevity as well as service and production improvement over time.

Since the manufacturing business has been successful, the company has diversified the manufacturing operations to accommodate cosmetics. Currently, CPG Ltd has manufacturing departments for producing and distributing liquid detergents, body cream, petroleum jelly and perfumes. Since inception, CPG Ltd has remained the provider of quality detergents and soap products. CPG Ltd seeks to continue producing quality soap products through improved manufacturing processes.

Since the establishment, CPG Ltd has expanded its own investment in the Nigerian market, increasing production capacity at the same time introducing new soap products and modern product technology. To control the inputs of production and ensure the right inputs are made, the company ensures that the same quality of oil, alkali and processes are used.

In the Nigerian manufacturing industry, the company is an exceptional phenomenon. The company provides the best soap brands enhanced by extensive research, studies on customer requirement, satisfaction and expectations, thus revolutionising the products delivered. So, the company puts more emphases on the quality of soap and detergent products. To ensure that that the required level of quality is met, the firm checks the input and output for quality conformity.

The household chemical sector has largely scrutinised companies manufacturing detergents and soaps in Nigeria. With increased awareness on public health and environmental concerns in the public, the company has thus focused on the minimisation of environmental impacts as well as packaging with respect to waste management. The company still operates in the dynamic landscape in which customers demand for perfect product labelling and information, safer packaging and improved product marking. Consequently, CPG Ltd provides testing and inspection services as well as supply chain monitoring processes geared towards addressing waste management and environmental needs, efficiently, and minimising disruption to production processes during soap manufacturing which relies on a combination of capabilities, involvement and performance of numerous, diverse parties. This causes inevitable challenge when data and expertise from all the parties are required. The challenge is even bigger when required data is incomplete, contradictory, complicated, indefinite, uncertain or inaccessible. To address this problem, a feasible and reliable approach is needed to first identify and represent dependencies of the sources of data and expertise related to the problem in hand and second to utilise the data and knowledge in an effective way. The need for IPPS across functions of CPG Ltd is illustrated in Figure 4-23 .

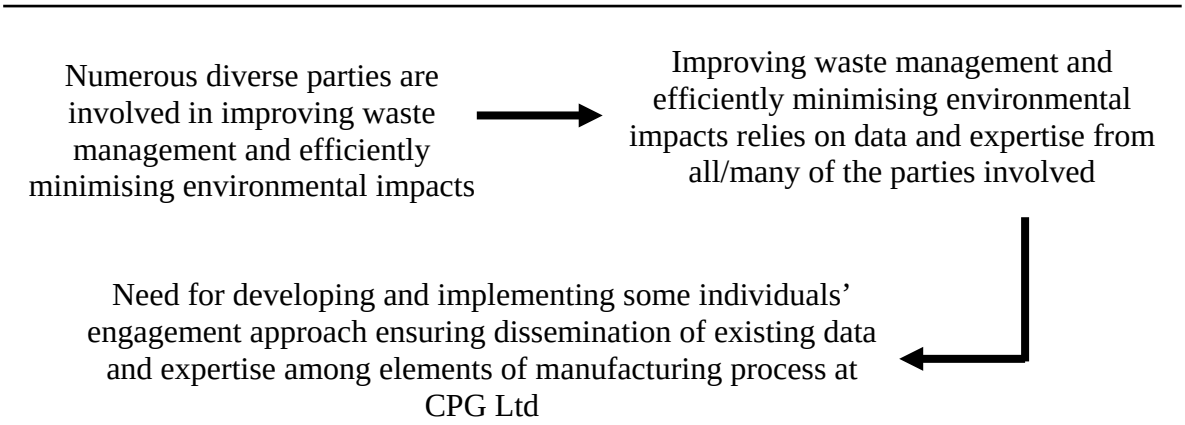

Figure 4-23. Model of factors shaping the challenge of improving waste management and efficiently minimising environmental impacts at CPG Ltd

There has been a remarkable lack of studies to highlight the potential relevance of utilising data in line with expertise for the purpose of improving waste management and efficiently minimising environmental impacts. The aim of the collaboration project with CPG Ltd was to address such a challenge, therefore, this research has implemented the new approach to IPPS, EC-FIKT, to enable information and knowledge transfer between resources and assist improving waste management and efficiently minimising environmental impacts.

The stages of the first phase of the EC-FIKT, designing the IPPS project, and the stages of the second phase, effective communication, will be described in this section.

4.3.2. Phase 1. Designing the IPPS project

Stage 1. Project initiation

Part one. Developing a clear purpose with IPPS team and identify information and knowledge domain

This approach to collaboration assist functions engagement in identifying the factors that supports improving waste management and efficiently minimising environmental impacts followed by productivity of CPG Ltd in their efforts to manage waste, effectively. By ensuring that all functions involved could contribute their information and knowledge and also benefit from the problem-centred experience of others, the purpose of collaboration was to assist information and knowledge transfer across the functions of CPG Ltd and develop solution for better understanding of the factors related to production waste and while also

providing the basis for further waste management-related collaborations. The project proposal clarified this purpose and the two initial participating groups – the researcher from University of Wolverhampton and representatives from CPG Ltd – understood the purpose explicitly.

It was clear that one of the key areas of concern for CPG Ltd has been improving and efficiently managing waste and environmental impacts. Improving waste management and efficiently minimising environmental impacts relies on many databases and work of many functions involved. This highlights the value and potential uses of data and expertise related to waste management and the need for developing and implementing intra-organisational engagement approach, ensuring dissemination of existing data and expertise among elements of this manufacturing company.

Part two. Engaging the right people in identifying required information and knowledge resources

Designing this collaboration required three essential sources of information and knowledge that are as follows:

- People with knowledge about factors that affect the production waste who can conduct intensive investigation of functions who have production waste-related information and knowledge

The CPG Ltd representatives involved in identifying the functions who have production waste-related information and knowledge and can contribute to the effectiveness of this collaboration.

The project leader, IKT expert from CPG Ltd, and the representative from CPG Ltd communicated the details of potential functions and individuals through Skype group meetings throughout this design phase. The project leader informed the other participants about the potential functions and individuals in the group meetings.

- Researchers who can collect the required production waste-related data for developing initial waste management models

The IPPS team at this stage involved of four individuals that are as follows:

- The researcher (IPPS leader)

- IKT expert from CPG Ltd (IPPS leader)
- The CPG Ltd representative – Production manager (IPPS leader)
- Production waste-related expert from CPG Ltd – Quality control analyst

The IPPS team, communicated through e-mail, telephone and had series of face-to-face meetings to review and discuss the relationship between project objectives and potential functions and individuals, and, they engaged through virtual environment only for sharing data and explicit ideas with the researcher (The communication between the members of IPPS team at this part is included in appendix A).

This extensive research was conducted with the objectives that are as follows:

- Identify and understand the nature and structure of key data streams within the different sections of the CPG Ltd
- Outline the relationship between such data sets into a series of models using suitable modelling tools and techniques.

Several sections of the CPG Ltd (e.g. production scheduling, operation etc.) were contacted with the aim of identifying and understanding their key data stocks and data flows.

The complexity of identifying sources of relevant data and the volume of data sources presented a challenge to the process of collecting and analysing the data, therefore, a series of models were developed based on the literature available, data resources and data structures provided by some functions/individuals. One of these models is shown in Figure 4-24.

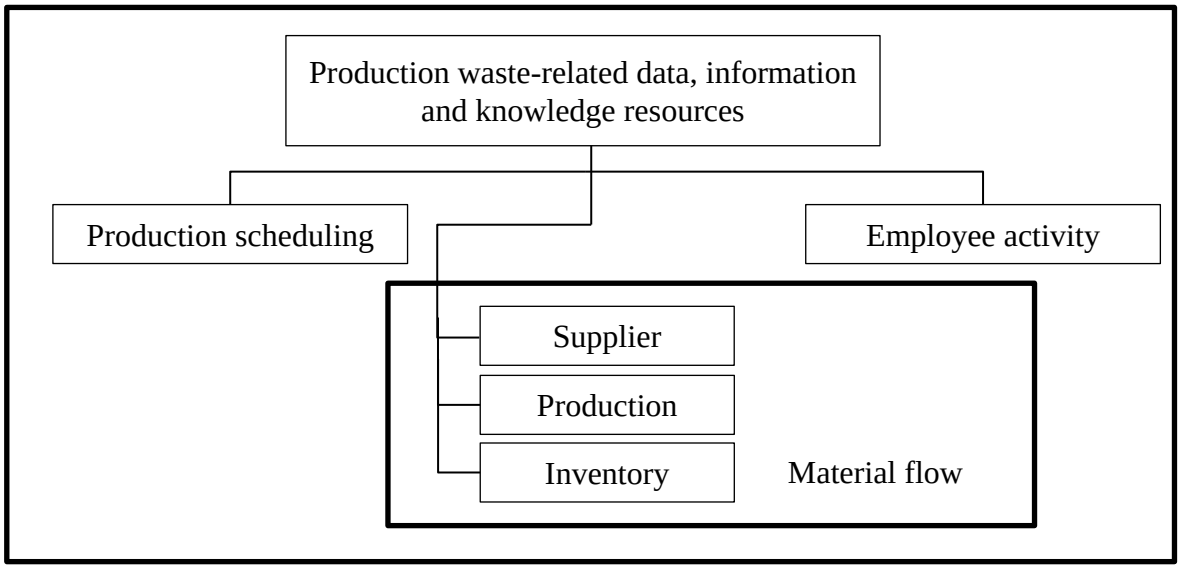

Figure 4-24. One of the models developed by the IPPS team

Developing these models also helped the IPPS team to better understand areas of work of the potential functions or individuals.

Stage 2. Project preparation

Part one. Selecting individuals with problem-centred knowledge for IPPS

Implicit in production waste-related decision-making is domain-specific information and knowledge that is difficult to derive, build and model for decision making. One source of such information and knowledge is professionals (from engineers to operators) in the domain that brings with them sources of implicit information and knowledge and point to explicit repositories. This is one important resource of information and knowledge used in the EC-FIKT approach to IPPS within CPG Ltd.

It was noted that different functions within the CPG Ltd collect data which is not always available to other functions of the company. Therefore, expertise from different sections of the CPG Ltd (i.e. analysts and operators) were evaluated to first identify and later understand their key data stocks and data flows and, more importantly, the perceived relevance of such resources for understanding production waste. Consequently, the selection of functions included, production waste and data experts from the main sections of the CPG Ltd. Twenty individuals who have production waste-related knowledge from different sections were selected to participate in the IPPS who can contribute to its purpose that are as follows:

- Seven Senior managers
  - Production manager
  - Production control manager
  - Inventory manager
  - Operations manager
  - Plant human resource manager
  - Quality assurance manager
  - Material manager
- Two Production technician
- Machine shop maintenance supervisor
- Two test engineers
- Two Inventory experts
- Scheduling expert
- Quality assurance engineer
- Quality control analyst
- Two Waste treatment plant operator
- Manufacturing process engineer

Part two. Inviting the selected individuals to engage in IPPS

In an industry such as manufacturing, where radical problem-solving will take place within the near future, learning from experience is an effective approach to understanding production waste.

Such learning from experience relies on two main resources: the volumes of data already available and the knowledge of production waste-related experts. Experts' knowledge is essential in the process of understanding the interrelation between all components of the manufacturing company (e.g. infrastructure, systems etc.). It would enable the manufacturing company to extract meaning from the data available. Therefore, the aim was to involve key experts from the CPG Ltd in IPPS.

The IPPS initial team considered the two important elements of inviting stakeholders to engage in collaboration that are who and when to invite. The team decided to recommend different dates to make it more flexible for the potential participants. The project leaders from CPG Ltd sent the meeting invites to the potential individuals two months prior to the event and kept track of the responses.

Part three. Planning the conceptual and structural requirements

The researcher followed the Design-shop method presented in section 4.2.2 (Phase 1: Stage 2: Part three) of this thesis.

4.3.3. Phase 2. People-based information and knowledge transfer

Stage 1. Effective communication

Context chart for individuals that engaged in the intensive collaboration Design-shop sessions is shown in Figure 4-25.

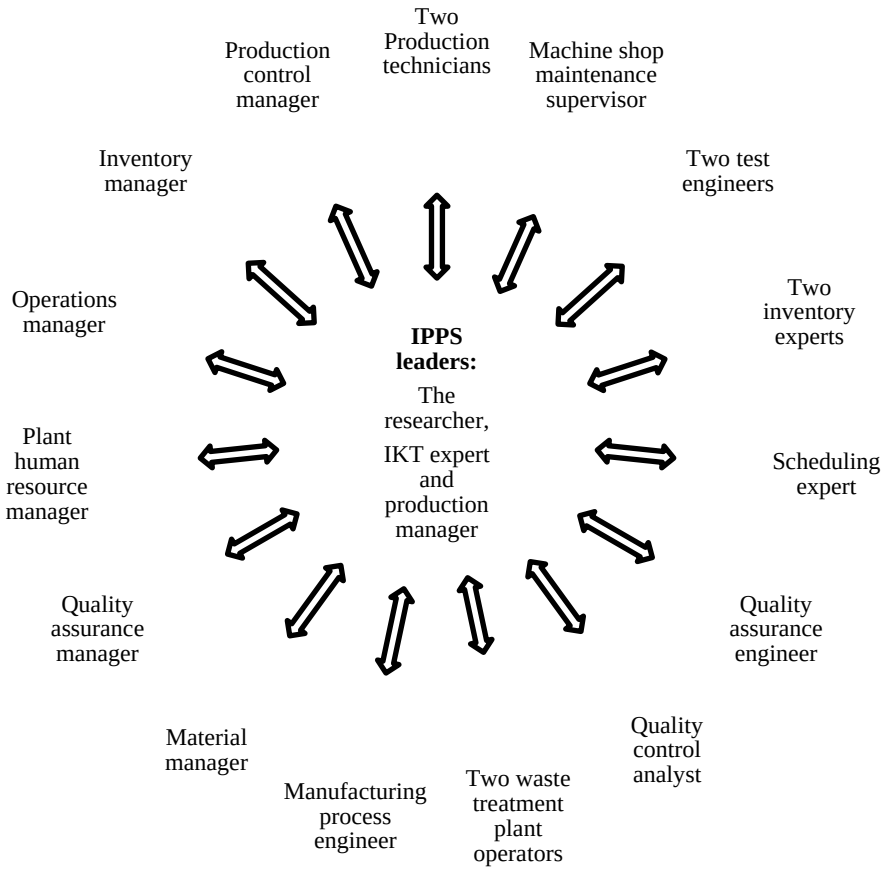

Figure 4-25. Context chart for individuals/functions participated in the IPPS at CPG Ltd

Part one. Clarifying the purpose of IPPS with participants

In the start of the Design-shop sessions, functions' attitude was defensive and focused on least compliance as opposed to seeing the management of production waste as being part of their broader role in CPG Ltd. Within the first hour of the first session, for example, there was general frustration and discomfort in communication between participants from different functions due to divergence definition of production waste and its importance for each group of individuals within the CPG Ltd. In addition, the possibility of being selected as the responsible function for the production waste or environmental impact, deepened the pressure across the group of participants and the unwillingness to listen to one another.

The IKT expert wanted to challenge and break down their usual pattern of not accepting the production waste's dependence on the effort of almost all the functions within this manufacturing company. One hour later, the communication form shifted, dramatically, from defending one's own performance to collaboratively focusing on finding answers to the bigger questions.

Part two. Engaging participants in sharing their perceptions of the problem

The topic was too generic. Although appropriate initiatives such as clarity of topic in the inviting phase, adjusting different perspectives and expectations right at the beginning of the sessions, and sharing experience took place to understand the influence of the problem on each participating function group, the perception of participants varied, significantly. The need for co-creating of topic clarity with the participants was inevitable. It became necessary to clarify what production waste means and distinguish between production waste management and environmental impact management. In order to do this, participants engaged in creating a series of questions to be answered. A sample of these questions is presented in Figure 4-26. Reviewing and discussing the answers to these questions resulted in clarification of the concept of production waste and environmental impacts.

Q. Is there a particular definition of 'production waste' for CPG Ltd?

Q. Is there a standard proven for waste analysis?

Q. Are there any organisational approaches to reduce waste-related events?

Q. Are there any organisational approaches to reduce environmental impacts at the design phase of the products?

Q. How to develop standard process?

Figure 4-26. A series of questions that supported co-creating of topic clarity

Part three. Creating credible problem resolution

It was important to create credible problem resolution that covers the wide range of factors that have many different influences on reducing production waste and environmental impacts. This was facilitated through engaging the participants in developing models that illustrated the relationship between those factors and their influences. One of the many models developed in this Design-shop is shown in Figure 4-27 (These models were reproduced in Microsoft Office format to retain and easily distribute a clearer version for participants and this research).

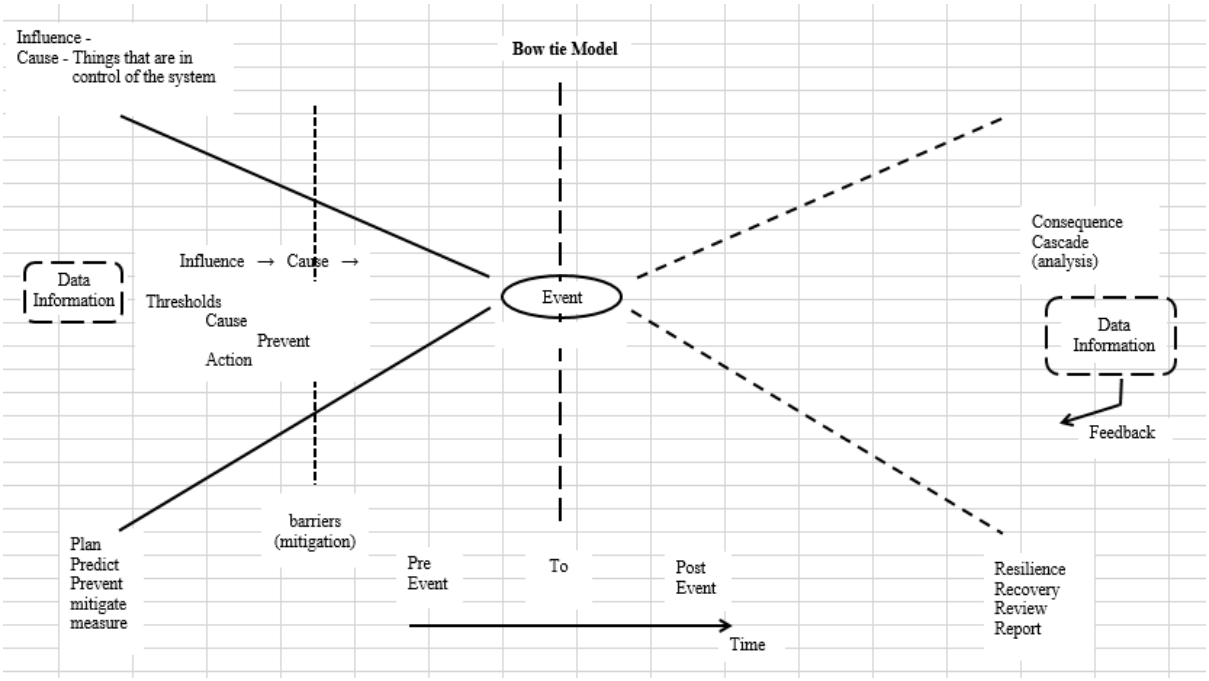

Figure 4-27. Initial model developed for creating credible problem resolution by participants

Part four. Engaging the participants in problem-solving

During Design-shop sessions, the group of participants focused on two key factors that are as follows:

1) The relationship between redundancies and production efficiency

   The group of participants focused on waste-related data and its management in two parts. During the first part, all the individuals participated in the discussion. 60% of the participants agreed that CPG Ltd adopts lean tools to eliminate redundancies thereby enhancing efficiency. Of this populace, 70% reported about using just in time method. manufacturing companies use just in time strategy to cut down inventory by supplying materials or components where required, in the amount required and when required. 65% reported CPG Ltd implements overall equipment effectiveness strategy. This strategy entails measuring the performance of equipment using performance, quality and availability. 60% reported that CPG Ltd uses zero defect, which are quality control practices geared towards eliminating identified deformities. 55% of this populace explained that CPG Ltd uses cellular manufacturing strategy to reduce redundancies. Cellular manufacturing (also called work cells) involves providing work settings in which personnel easily move between processes following the production of one assembly or model. 50% suggested value stream mapping as key in eliminating redundancies. Value

stream mapping is an important tool used in visually representing information and material flow, depicting how work processes relate, particularly non-value versus value adding activities. 40% indicated that CPG Ltd applies total product maintenance. This entails planning about equipment maintenance aimed at reducing downtime thus maintaining efficiencies.

During the second part, the facilitative leaders divided the participants into two groups, each group collaboratively added the relevant element to the models and at the next stage, the whole group designed the comprehensive models by sharing their findings.

2) Making the products less harmful for the environment

The major stages of product regulation include disposal, point of purchase, tax policies, product use, marketing, packaging and labelling and manufacturing. At each stage, organisations handle environmental protection regulations differently. The participants reported several mandates geared towards making their products less harmful to the environment. These mandates include packaging waste laws, landfill directives, electrical and electronic equipment waste directives, recycling strategies, hazardous waste control, waste shipment regulations, waste incineration laws, producer responsibility obligations and end of life vehicle laws. Of these regulations, 70% of the participants suggested that CPG Ltd largely schedule their manufacturing operations ensuring that they adhere to waste management and controls from production to shipment.

At this part of the session participants were divided into four groups that included individuals from different functions or different positions. They reported for addressing the environment was minimisation of waste and reduction of the cost of production. For instance, Group one indicated that very minimal amount of inputs turns out as waste, measured by the quantity of quality and acceptable output produced. CPG Ltd attains the goal by make sure workers apply safe manufacturing practices.

Moreover, Group four stated that the company’s inputs do not usually produce waste as most wastes are raw materials for other products. To address packaging and labelling laws, the participant indicated that their organization disclose ingredients used, provide warming labels and establish plain standard as gold standard. With respect to product disposal, the participant indicated that their organization has set environmental clean-up laws for all employees to adhere to. To reduce pollution, the participant suggested that

CPG Ltd secures all physical and chemical reductions to facilitate bioavailability by using irreversible degradation, to ensure that pollutants are not released again.

Group two suggested that CPG Ltd manages hazardous wastes by applying stringent control supply during production, transportation, inventory management and disposal or recovery. To comply with waste shipment laws, CPG Ltd controls how wastes move from the manufacturing company to the disposal or recovery destinations. To reduce pollution, CPG Ltd treats all discharges, wastes and reduce the utilisation of pollutant products.

The participants were asked to indicate if the quality of CPG Ltd product conform to internationally acceptable standard. Group one indicated always conformity, Group two indicated conformity, Group 3 indicated no conformity to a great extent and Group four indicated conformity in most cases.

60% of the participants suggested that CPG Ltd handle increase regulations to ensure environmental protection by designing products for reuse, reducing waste materials and encouraging recyclability. Another 60% suggested integrating costs related to waste management into the prices of the products produced while 65% suggested using recycling technology to promote innovation in manufacturing.

Stage 2. Review and reflect

Some participants suggested defect corrections as means to reduce redundancies thus enhancing efficiencies. By applying automation and improving the manufacturing process, CPG Ltd can reduce defects. Weak process control, inadequate training, incomplete engineering specifications and deficient maintenance case primary wastes, including rework, machine hours and inspections, hence must be addressed. Moreover, correcting malfunctioning machinery and reducing human errors help reduce wastes as well as redundancies.

A number of participants suggested that to reduce redundancies, CPG Ltd have implemented information management systems. These systems monitor and control the production process, hence permitting the workers to produce only demanded products. Generally, manufacturers are need to provide quality management systems alongside processes that address risks related to equipment. Manufacturers can implement standalone or integrated management systems to eliminate redundancies, reduce costs and promote effective management teams.

Participants suggested the application of web content management, transactional content management and collaborative content management systems in their organization.

4.4. Summary

This chapter presented the origins and foundations of the new approach to IPPS, EC-FIKT, in manufacturing companies on assisted collaborative use of problem-centred experience.

EC-FIKT has been described as a method for implementing the proposed approach in manufacturing companies. The characteristics of this method can be described in three steps that are as follows:

1. Creating credible problem resolution
2. Communicating perceptions of the problem across departmental boundaries
3. Identifying and engaging individuals with problem-centred experience in information and knowledge transfer

These characteristics and the relationship between them and success of IPPS has been described and an application of the method has been included in this chapter which can assist the manufacturing companies in the process of implementing this or similar methods.

The application of effective communication through facilitated information and knowledge transfer during collaboration with CPG Ltd has specified the methods reliance on the context. For example, during the development of EC-FIKT through collaboration with SMcorp, individuals were intrinsically motivated to share their experience with peers because knowledge sharing was a priority for this manufacturing company. However, implementation of EC-FIKT during the collaboration with CPG Ltd has identified that identifying and engaging individuals from diverse functions of a manufacturing company requires a more collaborative environment and IPPS leadership experience. Nevertheless, addressing these issues and the successful application of EC-FIKT verified the flexibly of the method to be adopted to the requirements of effective IPPS. It has also highlighted its feasibility to produce both implicit and explicit outcomes which may become particularly relevant for a manufacturing company or manufacturing companies within a specific domain.

5. Data collection and applications of the new approach to integration of process planning and scheduling in the field

The review of the literature, presented in chapter two, described the need for effective integration of process planning and scheduling and the key limitations of exiting approaches. Chapter three described the research design employed in this study to address some of these limitations and chapter four included the dimensions of a new approach to integration of process planning and scheduling which were developed and implemented as part of university-industry collaborations with two different manufacturing companies in Nigeria. In order to provide more specific information for the purpose of the assessment of the validity of this new approach, this chapter includes detailed description of data collected during the process of applying and refining the new approach.

5.1. The extent of the data collection process

5.1.1. The relationship between research problem and process of data collection

After identifying the need for new approach to integration of process planning and scheduling, the development and assessment of a new approach had become the focus of this research to answer the primary, general, research question outlined in chapter one which is as follows:

> *How do we minimise the limitations to existing manufacturing approaches which integrate process planning and scheduling in developing countries?***?**

Miles *et al.* (2014) remark that conceptual framework explains the key factors, variables or constructs to be studied which helps researchers to be selective and, as a consequence, decide what data should be collected and analysed. In order to do so, the researcher identified secondary, more specific, questions to consider areas that might influence the aim of the primary research question and he was keen to address them only as much as it was relevant to this research context (The descriptions of these research questions are included in chapter one). Analysis of this set of research questions assisted the researcher to design a conceptual

framework, which is shown in Figure 5-1, to select and follow the key issues in the process of data collection.

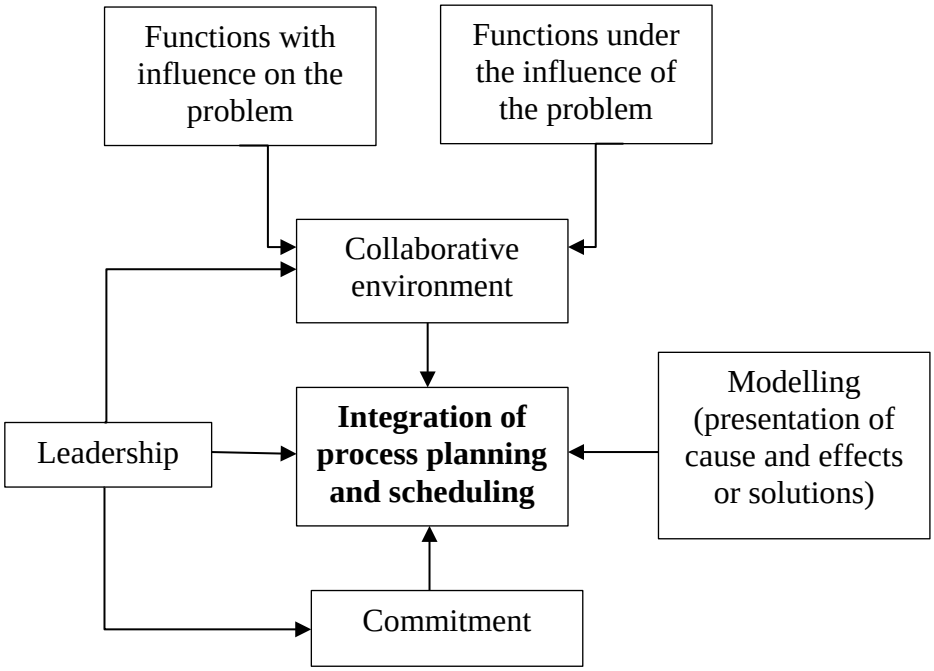

Figure 5-1. A conceptual framework designed for the study of the new approach to IPPS

The researcher attempted to collect primary data from the real fields to develop and then assess the feasibility of the new approach to integration of process planning and scheduling and its potential quality to eliminate or at least minimise some of the key limitations of existing approaches that are as follows:

- Functional boundaries are addressed to improve the complexity of information and knowledge transfer between different functions who have diverse identities and problem-related knowledge
- IPPS leader(s) assist information and knowledge transfer through an active control of the group dynamics
- Inviting the right people to engage in co-designing the collaboration supports selecting right functions and individuals to engage in the co-creation of new knowledge
- Clear purpose of collaboration and credible problem resolution are addressed to promote efficient information and knowledge transfer and effective problem-solving
- Identifying the factors influencing the problems facilitates addressing complex problems

- The new approach facilitates a collaborative environment within which all the participating functions and individuals contribute their problem-centred knowledge and benefit from the integration of process planning and scheduling
- The new approach facilitates the measurement of IPPS effectiveness and success

In order to facilitate verifying findings and conclusion of this research, which will be described in detail in chapter six, the researcher considered three essential factors during data collection process that are as follows:

- Selecting units of data which are most important and relevant to addressing research questions
- Displaying the selected units of data in a meaningful way
- Using these displays to draw conclusions on the validity of the new approach to integration of process planning and scheduling

5.1.2. Methods employed for data collection

The nature of research problem showed that empirical research is required to develop a new approach to IPPS. Moreover, to refine and assess the validity of the new approach, the researcher needed direct experience from the field. Therefore, data collection process presented in this research are driven by collaborations between the researcher and number of real manufacturing companies based in Nigeria throughout the development and implementation of the new approach to IPPS.

Yin (2014) emphasises that multiple case study research helps the researchers to gather compelling evidence and develop research that is more vigorous. Yin's multiple case study design that in relation to research question consist of set of two or more cases with exemplary outcomes was employed in this research to support the applications of the new approach to IPPS. As part of the multiple case study Four IPPS projects were conducted with four different manufacturing companies.

The researcher clarified the need for empirical multiple case study research and in order to attain required data through the application of IPPS during the collaborative projects with the manufacturing companies, he arranged the description of the sets of data to be collected, the methods to be employed for collecting them and estimated the outcome. These are described in Table 5-1.

Table 5-1. The set of data collected during IPPS projects in the field

Project stage	Method	Format	Data and its Application
Project initiation	Discussion between researcher and potential manufacturing companies	E-mail Meeting notes	Communicate manufacturing company's current problems Recommend IPPS and its potential benefits for the manufacturing company EC-FIKT evaluation in terms of motivation for problem-solving
	Communication between researcher and manufacturing company's representatives	Meeting notes E-mail	Identifying available resources to support the conduct of IPPS project EC-FIKT evaluation in terms of the need for IPPS leader
	Discussion between researcher and the representatives The researcher's observation	Meeting notes	Clarifying the purpose of IPPS EC-FIKT evaluation in terms of selection of the knowledge domain EC-FIKT implementation in terms of improving the researcher's understanding of the knowledge domain and noting the factors influencing the interaction between the researcher and manufacturing company's representatives during explaining, understanding and describing the knowledge domain
	Documentary evidence	Text document	Information about knowledge domain, reports from relevant previous project and sample data EC-FIKT implementation in terms of improving the researcher's understanding of the knowledge domain
Project preparation	Communication between the IPPS leader(s) and the manufacturing company's leader(s)	Meeting notes E-mail	Identifying availability and accessibility of required knowledge resources EC-FIKT evaluation in terms of identifying problem-centred knowledge and, as a consequence, selecting potential participants
	Communication between manufacturing company's leader(s) and potential functions	E-mail	Inviting the selected individual to participate in IPPS EC-FIKT evaluation in terms of motivation for participating in IPPS
	Documents	Text Network models	Information about the requirements of collaborative environment EC-FIKT evaluation in terms of its structural requirements

Table 5-1. The set of data collected during IPPS projects in the field

Project stage	Method	Format	Data and its Application
			EC-FIKT implementation in terms of its conceptual and physical environment
Effective communication	Qualitative text from participants	Qualitative text	key issues related to knowledge domain by the function who are affected by the problem EC-FIKT evaluation in terms of engaging participants in sharing their perception of the problem EC-FIKT implementation in terms of engaging selected individuals
	The relationship between key issues presented by participants and problem domain	Diagrams Tables Text	Display of the key issues related to knowledge domain by the functions who are affected by the problem or the ones who have influence on the problem EC-FIKT evaluation in terms of creating credible problem resolution
	Open-ended interview with available participants	Meeting and discussion notes	Identifying key issues related to problem domain EC-FIKT implementation in terms of engaging selected individuals and addressing complications of engaging diverse functions in IPPS
	Discussions between the researcher and available participants	Discussion notes	Validity of qualitative text from participants EC-FIKT evaluation in terms of issues that influence the communication between individuals EC-FIKT implementation in terms of engaging individuals
	The researcher's observation	Field notes	Key issues during group discussions EC-FIKT evaluation in terms of the need for IPPS leader during IPPS sessions EC-FIKT implementation in terms of leader's skill and experience of engaging individuals in collaboration
Review and reflect	Communication between participants	Developed solutions (in forms of text and models) Discussion notes	Final improvements and assessments EC-FIKT evaluation in terms of its effectiveness EC-FIKT implementation in terms of strengthening IPPS process

The analysis of interviews, documents and field notes including discussion and observation were the main research methods employed in this research and the reasons of employing qualitative research strategy of data collection process during the implementation of the multiple case study are clearly described in chapter three. The structure of this qualitative research strategy for the four case studies is illustrated in Figure 5-2.

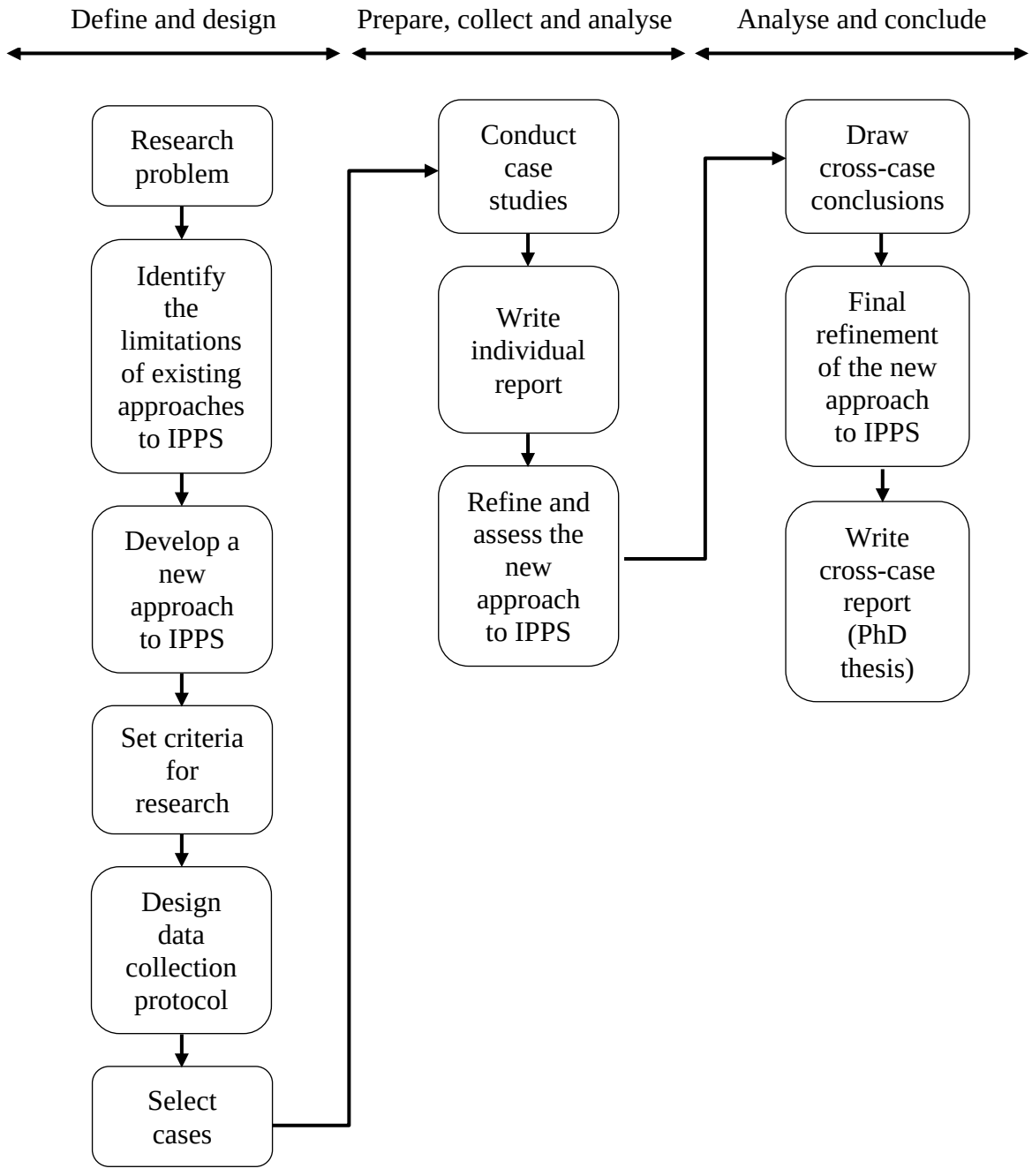

Figure 5-2. The structure of the multiple case study (adopted from Yin (2014; p. 60))

The remainder of this chapter includes the description of the field research, with emphasis on what data were collected throughout each IPPS project. The analysis of the data collected will be carried out in chapter six.

5.2. The implementation of the data collection

5.2.1. Introduction

In order to support the validation of the new approach to IPPS in the field, this section describes the data collection process. This description will start with the collaboration with SMcorp to demonstrate the origin of the first version of EC-FIKT for the reasons that are as follows:

- It assists the reader to clearly understand how the idea of IPPS through indicating and mapping factors affecting a complex problem in a domain and EC-FIKT as a method originated
- It assists the analysis of the data collected during the collaboration with SMcorp, which will be included in chapter six, for the purpose of verifying findings and assessing the validity of the proposed approach to IPPS

The description of the IPPS project with SMcorp will be followed by the description of the application of effective communication through facilitated information and knowledge transfer during the collaboration with CPG Ltd and two other manufacturing companies in Nigeria to clarify the sets of data collected and to demonstrate the pattern of EC-FIKT refinement as a result of its applications in the field. A summary of this refinement is displayed in Table 5-2.

Table 5-2. The EC-FIKT refinement as a result of the field research

Ep-s	Origins	Comments
Version 1 **(Practically effective for limited number of functions)**	SMcorp project (Leading manufacturing company in Nigeria)	Clarifying the purpose of IPPS with potential manufacturing companies needs to be addressed to eliminate the associated reluctance to share organisational knowledge with researcher(s) Involving the functions who are influenced by the problem is an important motive for effective IPPS Developing an environment that assists the participant in creating credible problem resolution can eliminate expending time, knowledge resource and effort on

		what is not required for the completion of IPPS IPPS leadership has an important role on the effectiveness of problem-solving
Version 2 (Practically consolidated for engaging number of diverse functions)	CPG Ltd	No significant changes to the process were made. However, the following issues were better understood: Impact of organisational support on the result of IPPS projects Impact of the problem-related experience of IPPS leader Positive impact of people-based approaches in comparison with technology based approaches on the result of IPPS

A concern emerged as a result of combining evaluation and refinement during the field work: would the data collected throughout the field work be compatible if the IPPS method being studied has changed as a result of its applications?

The researcher understood that data collected across the IPPS projects remained valid for the purposes of evaluation on the basis of the degree to which EC-FIKT was refined during the field work. Although it can be argued that EC-FIKT was refined, the fundamental process of it remained intact. In other words, the applications of EC-FIKT in the field allowed the refinement of the method to better implement the same approach to IPPS.

5.2.2. Leading IPPS projects

The strong relationship between the concept of leadership and IPPS was considered by the researcher throughout the design and implementation of the multiple case and data collection phase of the research. To address this issue he employed a combination of two approaches that are as follows:

1. In order to succeed in being IPPS leader where required by the IPPS process, he put extra effort to develop his understanding of the challenges associated with leading collaborations and available resources to address them through conducting intensive literature review on the topic of *leading collaborations* (Findings are presented in this research and in particular in relevant sections such as section 2.4.5 and section 4.2 – the IPPS leader.

2. Involving individuals who have expertise in leading collaborations or who could support the process when communicating with different functions of manufacturing companies was not feasible for the researcher

The combination of these two approaches helped this research to eliminate any negative effect of ineffective leadership on the result of the implementation of EC-FIKT and the data collected. It supported the researcher to collect the data he knew are essential for the assessment of the new approach and it addressed the limitations of the researcher's skills and experiment as a leader.

5.2.3. The origins of EC-FIKT: people-based IKT at SMcorp

The researcher collected the first primary set of data for the assessment and refinement of the new approach to IPPS during the collaboration between the researcher and SMcorp which formed the first IPPS project reported in this thesis. The uncertainty about the factors influencing SMcorp problem determined the researcher to consider involving the functions who are affected by the problem or who have an influence on the problem in problem-solving and as a consequence, the researcher developed the fundamental dimensions of effective communication through facilitated information and knowledge transfer that is referred to as EC-FIKT in this thesis.

A summary of the key steps of this project is displayed in Table 5-3.

Table 5-3. Key events of SMcorp project and identified dimensions of the new approach to IPPS

Part	**Event**	**Later formalised as dimensions of EC-FIKT**
One	Initial communication between the researcher and SMcorp representatives Reviewing of the aim of collaboration research through revisions of project proposal Discussion of required knowledge resources between the researcher and SMcorp representative Review of documents related to SMcorp problem by the researcher	Project design (project initiation)
Two	Discussion between the researcher and quality	Project design (project

Table 5-3. Key events of SMcorp project and identified dimensions of the new approach to IPPS

Part	**Event**	**Later formalised as dimensions of EC-FIKT**
	control analyst (an information and knowledge transfer expert) to clarify the availability of knowledge resources Identifying potential participants Initial communication with potential participants	preparation)
Three	Review of documents including reports and previous projects related to delays on the shop floor, available at SMcorp by the researcher Open-ended interviews with staff Observation of staff interaction on the shop floor Observation of staff training Identify the different factors influencing delays on the shop floor Display the relationship between delays on the shop floor and different aspects of manufacturing process at SMcorp	Effective communication
Four	Present the finding to SMcorp for review and assessment	Review and reflect

The SMcorp project implementation

The opportunity for collaboration was discussed between the researcher and SMcorp representative to identify potential project context and resources available to conduct the project. This project was not funded and for that reason it was important to select researcher who are willing to contribute to the implementation of the project. For the researcher, conducting empirical research and collecting primary data could have significant value for his PhD research in term of gaining insight and refining his new approach to IPPS and therefore, he was ready to contribute and benefit from the outcome of this collaborative project. The exchange of ideas and development of project proposal was discussed through series of meetings and e-mails between initial IPPS team, in particular, the researcher and quality control analyst from SMcorp who was an expert in conducting information and knowledge

transfer projects, and SMcorp representative who was an expert in addressing issues related to the process on the shop floor. Sample of the data collected at this stage is available in first section of appendix A that is as follows:

> SMcorp – Original data collected > project initiation > Summary of the communications between initial members of IPPS team

The experience of SMcorp representative and the researcher's area of research had important positive influence on developing most accurate project proposal at this stage. Moreover, the agreement on the content of the project proposal supported clarifying the purpose of IPPS project which could support effective start of the collaboration. These were identified as two important parts of project initiation during the project design.

The researcher and SMcorp representative had a series of meetings to discuss available resources, in addition to expert from quality control that could have information or knowledge related to problem domain. The researcher and SMcorp representative also exchanged documentary evidence through e-mails. As a result, a resource that included number of experts from different functions were selected. These experts were invited to participate in open interview and questionnaire mostly through e-mail.

Sample of the data collected and inviting experts to participate in questionnaire at this stage is available in sections of appendix A that are as follows:

> SMcorp – Original data collected > project preparation > open interview questions
>
> SMcorp – Original data collected > project preparation > consent letter
>
> SMcorp – Original data collected > project preparation > questionnaire
>
> SMcorp – Original data collected > project preparation > summary of participants input meeting

5.2.4. Application of EC-FIKT: IPPS at CPG Ltd

Dimensions of effective communication through facilitated information and knowledge transfer were developed and it was defined as a new structure approach to IPPS during the

collaboration between the researcher and SMcorp. The application of EC-FIKT took place through collaboration between the researcher and another leading manufacturing company in Nigeria, CPG Ltd. This collaboration with CPG Ltd was an opportunity for the researcher to implement the new approach to IPPS. The new approach to IPPS was conducted and summary of the key steps of this project is displayed in Table 5-4.

Table 5-4. Key events of the CPG Ltd project

Part	Event
Phase 1. Designing IPPS project	
Stage 1. Project initiation	
One	Part one. Developing a clear purpose with IPPS team and identify knowledge domain Part two. Engaging the right people in identifying required knowledge resources
Stage 2. Project preparation	
Two	Part one. Selecting individuals with problem-related knowledge for IPPS Part two. Inviting the selected individuals to engage in IPPS Part three. Planning the conceptual and structural requirements
Phase 2. People-based information and knowledge transfer	
Stage 1. Effective communication	
Three	Part one. Clarifying the purpose of IPPS with participants Part two. Engaging participants in sharing their perceptions of the problem Part three. Creating credible problem resolution Part four. Engaging the participants in effective communication
Stage 2. Review and reflect	
Four	Review and reflect

The CPG Ltd project implementation

The opportunity for collaboration was discussed between the researcher and CPG Ltd representatives to identify potential project context and resources available to conduct the project. This project could be a good opportunity to collect and analyse all data required to complete the researcher's PhD research as an extension of the lessons learned from his IPPS project at CPG Ltd.

This part of CPG Ltd project included drafting the project proposal, the agreement between the researcher and CPG Ltd representatives on the project deliverables and creating the initial IPPS team.

The results of the communication between IPPS team at this stage is included in appendix A in section that is as follows:

> CPG Ltd – Original data collected > project initiation > summary of communications between the members of IPPS team

This stage of the project included the process of selecting functions which could contribute to problem-solving and it was followed by identifying and selecting individuals from those functions who have production waste-related knowledge and could contribute to the IPPS. In order to involve individuals from different functions, whose experiences were essential for the purpose of this part of the project, introducing the IPPS project and the members of the IPPS took place by the CPG Ltd representatives who were well-known by those individuals or the functions. a summary of communication between the members of IPPS team and potential participant is included in appendix A in the section that is as follows:

> CPG Ltd – Original data collected > Project preparation > summary of communications between members of IPPS team and potential participants

Once enough data about potential contribution of selected participants and their willingness to engage in knowledge creation were collected, the researcher planned the design-shop and invited the selected participants to engage in EC-FIKT.

How version 2 of EC-FIKT was consolidated at CPG Ltd

Version 2 of EC-FIKT did not change significantly as a result of its implementation at CPG Ltd. However, this project provided an opportunity for learning in different areas of this approach. These areas are described in this section.

Project Initiation

Company-wide collaborative leader. The number of functions required to participate in the implementation of effective communication through facilitated information and knowledge

transfer at CPG Ltd increased significantly and it was important to consider the feasibility of involving collaborative leader(s) who are known by those functions within the manufacturing company. The senior managers from CPG Ltd addressed this issue which assisted the process of identifying, selecting and engaging many functions with diverse identity during the application of EC-FIKT to IPPS.

Management support. The implementation of EC-FIKT at CPG Ltd had full support from the senior managers of all the participating manufacturing companies.

Project preparation

IPPS meetings. It became evident that the IPPS meetings that could facilitate face-to-face meetings between all the specified participants at one time and location would significantly reduce the amount of time required from individual participants to contribute and reduce the amount of time and effort required from the IPPS leader(s) to capture and disseminate problem-related knowledge of the participants. It also could contribute to the effectiveness of problem-solving activities.

Information and knowledge transfer meetings

Duration of the meetings: The length of the meetings was significantly different in the CPG Ltd project, with the IPPS participants spending two full days of collaborative mapping, reviewing and improving data models

Visual mapping: The application of EC-FIKT to IPPS benefited from engaging all the participant, simultaneously, in developing extensive visual mapping of the factors influencing the problem.

Leadership: While the researcher added the experience of the approach being used, the CPG Ltd leader had the experience of the subject being discussed.

The key lessons learnt from the application of EC-FIKT at CPG Ltd are summarised in Table 5-5.

Table 5-5. Key lessons learnt from the application of EC-FIKT (version 2) at CPG Ltd

Ep-s stage	Key issues
Project initiation	Collaborative leader(s) can have an important role in identifying and selecting diverse functions during IPPS process. collaborative leaders can also ease the communication between diverse functions

Table 5-5. Key lessons learnt from the application of EC-FIKT (version 2) at CPG Ltd

Ep-s stage	Key issues
Project preparation	Particular importance of people-based approaches for creating conceptual environment when effective problem-solving requires collaboration between varying number of diverse functions
Effective communication	The number of meetings and the duration of the meetings are determined by the perception of the IPPS team or the practicalities of their implementation. Version 2 of EC-FIKT is flexible enough to allow as many meetings as the team considers necessary It was observed that version 2 of EC-FIKT is not dependent on the researcher acting as a IPPS leader. Different collaborative leader(s) could add their own perspective to the approach if they are fully committed to achieving best results. Also, the approach worked with leader(s) from different professions.

After applying the new approach to IPPS in different manufacturing companies, the collaboration with CPG Ltd suggested that version 2 of EC-FIKT was stable.

At this stage, the researcher considered that enough data had been collected and that it was appropriate to conduct the cross-case analysis of those data. No more field work was strictly required to the aims of addressing the research questions that had driven the data collection process.

5.3. Summary of data collection process

The new approach to IPPS has been validated and refined after its initial design and development at SMcorp which was followed by its application at CPG Ltd during which seven senior managers from diverse functions participated in the research reported in this chapter. Influence

A number of factors that inspired the data collection process are as follows:

- The primary research question that leads this research
- The set of additional research questions that are described in chapter one
- A conceptual framework that illustrated the key concepts to be studied and the relationship between them that is presented in Figure 5-1

The structure of the data set collected during the implementation of each of the KET exercises in the field is presented in Table 5-1.

During the application of EC-FIKT in the field, assessment and refinement of the method have been successfully included. Thus, the field work has produced a reliable approach to IPPS in manufacturing companies and the data that would enable its evaluation.

As described in section 5.2.1, the researcher was aware of the fact that combining EC-FIKT assessment with its refinement may have affected the conclusions that could be drawn from the data collected. However, the value of the contribution to the body of knowledge by this approach to conducting the field work outperforms the limitations it imposes to the evaluation of the method.

The following chapter will describe the analysis of the data collected.

6. Assessment of the new approach to integration of process planning and scheduling

A new approach to integration of process planning and scheduling has been developed in order to address the set of research problems identified during early stages of this research. The descriptions of the elements of this new approach and data collection and analysis during the development and implementation of it has been included in previous chapters.

This chapter describes how these data were processed, condensed and presented for the drawing and verification of conclusions that address the research problems.

6.1. The analytic method employed by this research

6.1.1. Complexity of the data analysis

The previous chapter presented that a large amount of data was collected during the application of a multiple case study. This chapter will describe the methods that the researcher employed to use these data in order to evaluate EC-FIKT.

The nature of qualitative data collected in this research suggests that an interpretive approach would be required for analysing these qualitative data. Therefore, this research employed interpretive approach to analyse the primary qualitative data which had been collected mainly through observation, open-ended interviews and e-mail communication.

Spencer *et al.* (2014) specify that the term *data management* refers to the process of making qualitative data *manageable* which is essentially required for sorting mass of data. Miles *et al.* (2014) remarks that data management covers what to store, retrieve from and retain. Qualitative data collected during this research is a resource of rich description and explanation from several resources within multiple case studies and for these reasons data management was very important for the researcher. Spencer *et al.* (2014) remark that transferability or generalisation of qualitative research from the context of the research to other settings or contexts adds to the challenges associated with qualitative research.

In this research, providing evidence of the applicability of the new approach to IPPS in other manufacturing companies and by other individuals different from the researcher who implemented, assessed and refined it in the field was another challenge of qualitative data for the researcher. In addition to the challenges associated with qualitative data analysis, case study data analysis is especially difficult. Yin (2014) explains that the difficulties of analysing data collected through case study is based on lack of feasible techniques to carry out such analysis. Another challenge associated with qualitative data analysis is the impact of researcher's conceptual thinking on the employed process of data analysis is more significant than the employed methods.

Regardless of different perspectives of authors, referred to in this research, on the benefits, limitations and difficulties of qualitative research, they (Bryman and Bell, 2015; Miles *et al.* 2014; Silverman 2013 and Spencer *et al.* 2014) agree on the importance of trying to achieve two key objectives while carrying out qualitative data analysis that are as follows:

1. Focusing on the high-quality accessible data and documentation of just the analyses that have been carried out
2. Transforming the data into something meaningful for the research and its audience

6.1.2. Outline of the analytical process employed by this research

In order to achieve the two key objectives of qualitative data analysis in case study research, this research followed a combination of analytic process suggested by case study research guide of Yin (2014) and analytic process suggested by most popular authors in the area of qualitative data analysis that are Bryman and Bell (2015), Miles *et al.* (2014) and Silverman (2013). This analytical process comprises three elements that are as follows:

1. Identifying evidence to address research question(s)
2. Employing the most reliable evidence to draw a conclusion
3. Clearly presenting the evidence to support the validity of the conclusion

This research, follows Miles *et al.* (2014) three streams of analysis activity to present the principles employed to address these elements of the analytical processes of qualitative analysis. The three streams are as follows:

1. Data condensation

Data condensation, type of the coding of data, is a part and form of analysis that presents researchers' analytic choices of refining, arranging, focusing, discarding and organising data. Some authors refer to the process of selecting, focusing, simplifying, abstracting and/or transforming the data collected through field notes, interview transcripts, documents and other empirical materials as *data reduction* process which is essential for dealing with mass of data. Miles *et al.* (2014) refer to this process as *data condensation*. They explain that this term presents the effort of researcher(s) on making the data stronger while the term *data reduction* might be understood as weakening or losing something during the process.

The primary set of qualitative data collected during each application of EC-FIKT in the case studies included data relevant to the purpose of implementing the IPPS projects and also relevant data required for evaluating EC-FIKT. the next step was to select the data set and transform every piece of field notes and transcription of semi-structured and open-ended interviews and other empirical material that was relevant for the evaluation of EC-FIKT into text in compact forms.

2. Data display (Matrix)

Miles *et al.* (2014) refer to data display as matrix which, similar to data condensation, is part and key flow of analysis activity. They explain that this analytical activity assists researchers in conclusion drawing and action through supporting them in presenting an organised and compressed assembly of mass qualitative data which can be in the form of conceptual framework and network displays to show the interrelationship between variables or table displays that helps the researcher to decide on the rows and columns and the type and form of data to be included in each cell. This part of analysis is particularly essential for supporting the researcher in organising *extended filed notes* into an immediately accessible and compact forms.

Tables, conceptual frameworks and network models are employed in this research to display the most important aspects of the collected cate study qualitative data which assist the readers in conclusion drawing through understanding the factors influencing the process of implementation of each IPPS project in the multiple case study.

3. Conclusion drawing/verifying

Miles *et al.* (2014) emphasise that it is important for qualitative researchers to pay particular attention to maintain openness in the early stages of noting patterns, explanations, causal

flows and propositions. They explain that the initial inexplicit conclusions assist researchers to create correspondence between final conclusions and size of field notes, the coding, storage and retrieval methods employed in the research. Moreover, they emphasise that conclusions are also *verified* as the primary research proceeds. Conclusion verification illustrates the validity of the findings to confirm the conclusions through revisiting the data collected.

In this research, the results of the analysis of data collected from the application of EC-FIKT within each IPPS project were used to generate theoretical constructs. These theoretical constructs were then grouped into conclusions.

The relationship between these three streams – types of analysis activity – and the activity of data collection itself is shown in Figure 6-1.

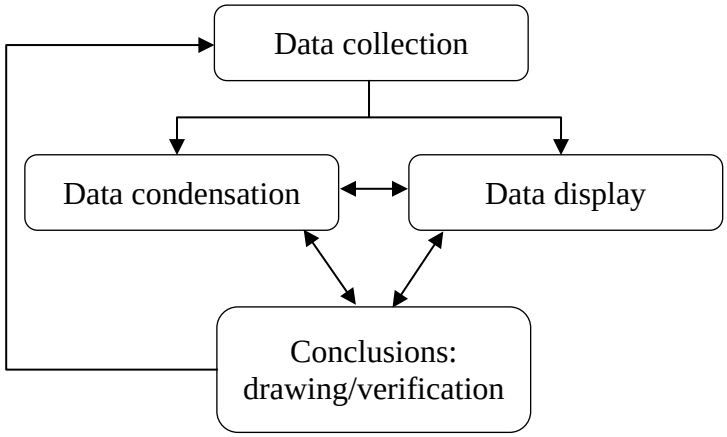

Figure 6-1. Components of data analysis: Interactive model (Miles and Huberman, 1994; p-12)

6.1.3. Quality of findings and conclusions derived from analytical approach to data analysis

In order to address the critical need for clarifying the validity of findings of this research to show that it is rigorous and competent, this section of the thesis addresses the challenges associated with testing or confirming the findings and validating the quality of conclusions.

Tactics for confirming findings

Checking for researcher and participants bias

1) Researcher bias

Eisenhardt (1989) emphasises that in addition to being affected by more powerful participants, insufficient data and disconfirming evidence followed by irrational conclusions is the result of researcher bias in data collection and analysis. Miles *et al.* (2014) remarks there are two possible source of researcher bias that are as follows:

1. The effect of the researcher on the case (during the field study)
    - Unknown position of the researcher for other people in the environment where the research is taking place. Individuals will perceive the researcher as an outsider which has negative impact on the accuracy of data collected)
    - Unknown purpose of researcher's presence for other people. individuals will be less honest the information they might share with the researcher or they might change the way they work other times)
    - Unknown purpose of the research. Individuals might not participate in information or transfer when they do not know what might be done with their experience or information being collected)

To address these biases, the researcher made every effort to employ approaches that could help him in avoiding these biases. These are as follows:

- The researcher made sure that he is introduced to participants and his role is described by the manufacturing company's representative prior to any IPPS related activity including semi-structured interviews, open-ended interviews, meetings or observation process. In the absence of this opportunity, the researcher dedicated some time to introduce himself and describe his role at the beginning of any of these processes.
- Clearing the purpose of IPPS had its specific part throughout implementation of the new approach and because of its significant impact on the effectiveness of IPPS process, every effort was made by the researcher that clearing the purpose was neither neglected nor omitted.
- The researcher planned to conduct informal discussions with participants in a social, experimental and systemic environment for effective IPPS.

2. The effect of the case on the researcher

Biases originated by the effect of the researcher on the case increase the occurrence of the bias caused by the effect of the case on the researcher. To address these biases, the researcher

planned to employ techniques that could help him in avoiding these biases in this research. These are as follows:

- The researcher needed to investigate different functions and individuals' perspective as the method of investigating divergent data collection and analysis to address this type of researcher bias. Therefore, this research explored individuals' needs and expectations within each group of functions in line with their perspective and expectations from each another.
- Keep thinking conceptually; translate sentimental or interpersonal thoughts into more theoretical ones. This technique helped spanning some boundaries to add to the effectiveness of IPPS.
- In case of sensing being misled, the researcher reviewed available evidence and discussed the matter with experts to assure reliable data were collected.
- Triangulate with several data collection methods.
- This research needed the participants to share their problem-centred experience without being concerned about any negative impact of it on themselves or their manufacturing company. Therefore, building mutual trust between participant and the researcher and between participants themselves was one of the key actions during the conduct of this research.

2) Participant bias

Eisenhardt and Graebner (2007) emphasise that the researcher has to value the participants' different perspectives in addition to understanding the importance of different perspectives on the effectiveness of collaboration. This helps the researcher to reduce participant bias and turn it into the elements of better understanding the factors that influence the development of boundaries between individuals and different groups of stakeholders. The new approach to collaboration developed in this research facilitated an environment within which the individuals had the opportunity to express their perspective. It supported the better understanding of the interconnectedness of different factors that develop the problem affecting the domain that resulted in creating credible problem resolution.

The pressure on participants who feel that their perspective and experience has no value for the other participants and they need to express only what others accept as reasonable affects participant bias. One of the potential factors that creates bias is the power difference between

the participants and the researcher. In the case of this research, it was very important for the researcher and purpose of his collaboration with manufacturing companies to provide an effective collaborative environment that addresses the issues related to power differences through building mutual approval that all the participants agree on the benefits of their contribution to IPPS for their manufacturing companies.

Triangulating

Triangulation, a near-obligatory method of confirming findings of qualitative research (Miles *et al.*, 2014), is one of the key components of case study research (Denscombe 2007; Yin 2014). The importance of triangulation in interpretive paradigm revolves around investigating the extent to which different sources of data support the researcher to understanding the aim of the research.

The importance of interpretive paradigm lies in the researcher's intent to bring understanding about the aim of the research and the extent to which any one source of data adds to that understanding or clarifies between conflicting meanings. This research maintains triangulation to gain maximum possible understanding from multiple perspectives.

Triangulation of data is the method of collecting evidence from multiple data sources and methods. Miles *et al.* (2014) affirms that qualitative researchers are always faced with triangulating data either intentionally or unintentionally. Triangulation can be described by *data source*, by *theory*, by *method* and by *theory* (Denzin,2001; Denzin and Lincoln, 2017) or *data type* (Miles *et al.* 2014). Data sources in this research included individuals from different functions and the collaboration's structural environment varied during the implementation of EC-FIKT in the multiple case studies. The researcher employed different methods such as transcription of observations, filed notes and open-ended interviews. The researcher was aware that triangulation can add to the complexity of data analysis and to prevent this, he focused on qualitative analysis rather than combination of qualitative and quantitative analysis.

Tactics for confirming quality of conclusions

To address the challenges associated with epistemological perspective that focus on the ways of fitting research findings into what is accepted body of knowledge, this research focused on the more practical *critical realist tradition* perspective of Miles *et al*. (2014) which pairs traditional terms of *naturalistic* perspective of Lincoln and Guba (1985) with more viable

alternatives for assessing the reliability and validity of naturalistic research. Therefore, the five key, somewhat overlapping, issues related to standards for quality of conclusions employed in this research are as follows:

Objectivity/confirmability

The research conclusions need to be reasonably devoid of unacknowledged researcher biases and explicit about inevitable biases that exist. Tactics employed by the researcher in consideration of this issue are as follows:

- He included explicit and detailed description of the employed methods and procedures for data collection and analysis of each IPPS project in the body of this thesis, including appendixes, to present all the required information to provide a complete picture for drawing conclusions
- He presented a clear sequence of how data were collected during each IPPS project, processed, condensed or transformed and displayed to assist specific conclusion drawing
- He was aware of the issues related to personal biases and described how he addressed them during IPPS projects at the beginning of this section (Checking for researcher and participants bias)
- In addition to the available actual data collected in the body of this thesis, some of the data collected are condensed or transformed for the purpose of this research and some data (e.g. actual identification of resources, including individuals and manufacturing companies) has been altered to maintain confidentiality and anonymity throughout this thesis. However, the researcher retained all the actual data collected and they will remain available for reanalysis by others where required and agreement with participants is maintained.

Reliability/Dependability/Auditability

Consistency of the process of the study demonstrates reliability of the qualitative research. The factors considered by the researcher about the issues of quality and reliability of conclusions are as follows:

1. He included a clear research questions and worthy relationship between the research questions and research design, in this research. Moreover, the concept of

research problem is clearly specified in the primary and secondary research questions and the reasons for the chosen research design to address the research questions is discussed in detail.

2. The researcher's role and status within the case studies are explicitly described in the relevant chapters of this thesis.
3. The findings show meaningful parallelism across data sources, in this research, and all the data collected and the reports written were organised according to its contexts, which was identified by the relevant case, type of event, dates, people involved and stages of IPPS process related to each document produced.
4. Research paradigms and analytical constructs are clearly specified in section 3.3.
5. The process of data collection addressed the required data suggested by the research questions including range of appropriate knowledge sources and knowledge creation settings.
6. Data quality checks have been made (e.g. for bias, deceit – this is described in detail at the beginning of this section, under Checking for researcher and participants bias, and section 3.5. Internal validity/Credibility/Authenticity

In order to address the credibility of the research, it was essential that the researcher had an *authentic portrait* of what he was studying and assist the research participants and readers in finding meaning and coherent in conclusions of the research. The factors supporting this issue are as follows:

- This case study research revolved around scholarly questions that merits this research
- In this research, the problems associated with engaging diverse functions in effective information and knowledge transfer are investigated and addressed through triangulation which supported the use of different sources of data and findings within this research that allowed better understanding of the IPPS process
- The description of the research design and methodology in this thesis assists the reader to determine the research quality
- There is significant evidence that the data was collected by applying the process for IPPS defined in chapter four of this thesis

- The thesis included the negative evidence identified throughout the development and implementation of EC-FIKT and described that either they resulted in refinement of the method or identifying factors influencing characteristics of it

- This research involved the original participants in IPPS projects in describing the accuracy of the conclusions

External validity/Transferability/Fittingness or Generalisation

The degree of which the findings of the qualitative research can be of relevance beyond the sample and context of the research itself is a critical challenge in particular for case study approach. In order to illustrate the transferability of this research, the researcher considered useful points that are as follows:

- Although identities of manufacturing companies or individuals involved in the multiple case study have not been revealed in this thesis, their characteristics have been described to an extent where a reasonable understanding of the reported IPPS projects is possible.

- This research involved diverse sample of manufacturing companies and individuals in IPPS projects. As a consequence, in the application of EC-FIKT different types of problem-related information and knowledge have been considered. This empirical evidence from multiple-case study suggests that the application of EC-FIKT is likely to achieve reasonable levels of success in other manufacturing companies within sectors that at least include the ones represented in the multiple case study.

Utilisation/application/action orientation

In order to demonstrate the value of conclusions for the participants and potential users, including individuals and manufacturing companies, of this researcher, the researcher employed some useful points that are as follows:

- Ethical concerns are described explicitly in this thesis. This is included in section 3.5.
- The findings of this research has been intellectually and physically accessible to its potential users
- The action taken by this research has been beneficial for:

- The involved manufacturing companies in terms of sharing problem-centred information and knowledge to solve complex problems
- For the researcher in terms of developing new approach to IPPS and collecting enough evidence to validate the findings towards completion of his PhD research

– The definition of the new approach to IPPS has been included in chapter four and it has been explicitly documented as a result of this research to assist its application by potential users

6.2. The process of condensing the data collected

6.2.1. Introduction

Data collected during the field research were in different forms including field notes, e-mails exchanged between the participants, notes from open-ended interviews, IPPS meetings, and design-shop sessions that involved individuals from the manufacturing companies engaged in the multiple case study.

The researcher recorded most of the field notes, that he collected throughout this research, in notebooks. These field notes contain valuable pieces of data collected during the field research that summarises important ideas that were essential for running IPPS. The sections of the notes which include many codes that lead to clearing the relationship between different filed notes are mostly understandable only by the researcher.

The researcher also collected various number of e-mails over the course of field research. In addition to valuable data for running IPPS projects, these emails contained explanations of very specific problem-related data such as specifications of delays at SMcorp shop floor or specifications of production waste-related information at CPG Ltd which were only valuable for the participants form the involved functions. Therefore, most of the details included in the e-mails by the participants provided significant input to the problem-related data set to be analysed during the IPPS meetings and did not provide a significant input for the purpose of assessing the validity of the new approach to IPPS. Moreover, some of those e-mails contained information that was only relevant at the time that they were sent or received, e.g. those e-mails related to times and venues of meetings. Therefore, it was essential for the researcher to significantly reduce the data collected through e-mails.

Spencer *et al.* (2014) clarify that essential part of analytic process of investigating qualitative data is to reduce the original data from their raw form of documentary evidence, observation notes, verbatim text and any other data in order to enable the researcher to make sense of the evidence. However, as they emphasise, the process of reducing data should not affect the meaning of original terms, thoughts and view of the study participants. Therefore, it is important to partly capture synthesis in a way that leads to recognising the original material. Miles *et* al (2014) refer to this process as coding which is a *data condensation* task for the reason that codes are *prompts* for deeper reflection on the data's meanings. Therefore coding enables the researcher in terms of decisions such as which data chunks to code and which to pull out, which patterns best summarise a number of chunks and which story to tell as described in section 6.1.2. To achieve the aim of condensing the data collected, the researcher employed two key steps that are as follows:

1. Coding the data

   This steps included meaningfully dividing sets of collected data after reviewing the field notes while maintaining the relation between the data sets through two stages of coding that are as follows:

   - Summarising segments of data by assigning units of meaning to the data collected using tags or labels. Saldaña (2015) refers to this stage as first cycle coding methods that are codes initially assigned to the data chunks
   - Grouping those summaries into a smaller number of categories, themes or constructs by looking for patterns (Miles *et al.*, 2014). Saldaña (2015) refers to this stage as second cycle coding methods that pull together a lot of material from first cycle coding. Miles *et al* (2014) refer to the second cycle coding as pattern coding.

2. Developing theories based on the identified patterns

   A theory in this research is considered to be *a description of the pattern that the researcher finds in the data* (Auerbach and Silverstein, 2003; p. 31). The researcher focused on developing theories that were relevant for the factors that drove the data collection which are outlined in section 6.1.1.

The remainder of this section revolves around describing each of the steps followed during the analysis of the data collected during the implementation of the multiple case study.

6.2.2. First cycle codes and coding

Coding is a method that allows the use of words to assign meaning to a piece or chunk of data which could be in a form of a phrase, sentence or a paragraph (Bryman and Bell, 2015; Miles *et al*. 2014; Myers 2013; Silverman 2013). Following the Lichtman's (2014; p.329) description of initial coding and Miles *et al.* (2014; pp. 77-78) definition of *provisional coding* which is an explanatory coding method that is appropriate for qualitative research that build on or confirm previous research or investigation, the researcher understood coding as the process of grouping words together into conceptual groups that represents ideas which can be related to at least one of the three categories that are as follows:

1. The research hypothesis
2. The research questions and related conceptual framework
3. The literature review that outlines the limitations of existing approaches to IPPS

Table 6-1 presents the list of the researcher-generated codes used in this research and Table 6-2 presents the definitions of the codes.

Table 6-1. The list of codes used in this research

Category/Code	**Code**	**Source**
Category: Limitations of existing approaches to IPPS	**LIM**	Literature review, primary research question, hypothesis and conceptual framework
LIM: Demands	LIM-D	Literature review, primary research question, hypothesis and conceptual framework
LIM: Departmental boundaries	LIM-DB	Literature review, primary research question, hypothesis and conceptual framework
LIM: Information and knowledge transfer	LIM-IKT	Literature review, primary research question, hypothesis and conceptual framework
LIM: Motivation	LIM-M	Literature review, primary research question, hypothesis and conceptual framework
LIM: Problem-centred information and knowledge	LIM-I&K	Literature review, primary research question, hypothesis and conceptual framework
LIM: Collaborative leader	LIM-CL	Literature review, primary research question, hypothesis and conceptual framework
LIM: Problem-solving	LIM-PS	Literature review, primary research question, hypothesis and conceptual framework
Category: Group dynamics	**GD**	Literature review, RQ3, hypothesis and conceptual framework
GD: Trust	GD-T	Literature review, RQ3, hypothesis and conceptual framework
GD: Communication	GD-Com	Literature review, RQ3, hypothesis and conceptual framework
GD: Leadership	GD-Lead	Literature review, RQ3, hypothesis and conceptual framework

Table 6-1. The list of codes used in this research

Category/Code	**Code**	**Source**
Category: The new approach to IPPS	**NIPPS**	Literature review, hypothesis and conceptual framework
NIPPS: Participants	NIPPS-P	Literature review, RQ6, hypothesis and conceptual framework
NIPPS: Conceptual environment	NIPPS-CE	Literature review, RQ6, hypothesis and conceptual framework
NIPPS: Technology	NIPPS-T	Literature review, RQ5, hypothesis and conceptual framework
NIPPS: Problem-solving	NIPPS-PS	Literature review, RQ2, hypothesis and conceptual framework
NIPPS: Outcomes	NIPPS-O	Primary research question, hypothesis and conceptual framework
Category: Evaluation of IPPS success	**EVAL**	Literature review, RQ6, hypothesis and conceptual framework

Table 6-2. Definition of the codes used in the data analysis

Code	**Definition of data**
Codes related to the limitations of existing approaches to IPPS (LIM). The selected codes in this category are used to group issues that challenge the success of existing approaches to IPPS in the relevant literature that could lead to the development of the new approach to IPPS	
LIM-D	The data that are relevant to understanding the effects that the demand of the application of the new approach might have on the success of IPPS
LIM-DB	The data that are relevant to understanding the impact of departmental boundaries on the success of IPPS projects
LIM-IKT	The data that are relevant to understanding the impact of information and knowledge flow across different functions of manufacturing company on effectiveness of IPPS
LIM-M	The data that clarify the relationship between participants willingness to participate in IPPS project and contribute to its success
LIM-I&K	The data that identify the role of skill, knowledge, experience and expertise on the effectiveness of IPPS
LIM: CL	The data that explain the extent to which skilful leader(s) can improve the process of IPPS
LIM-PS	The data that assist the researcher to distinguish IPPS applied to solve problems from the ones employed for productivity
Codes related to group dynamics (GD). The selected codes in this category are used to group issues that show the extent to which EC-FIKT considers the lessons learned from the field of group dynamics in an attempt to achieve better results in terms of IPPS	
GD-T	The data that include the relationship between trust among IPPS participants and success of EC-FIKT to IPPS
GD-Com	The data that identifies the relationship between process of communication of ideas, information and experience where contributions are not restricted to specific group members can take place during the implementation of EC-FIKT
GD-Lead	The data that identifies the relationship between IPPS leader's problem-related knowledge and effective problem-solving
Codes related to the new approach to IPPS (NIPPS). The selected codes in this category are used to group issues that are relevant to describing the extent to which specific characteristics of the new	

Table 6-2. Definition of the codes used in the data analysis

Code	Definition of data
approach can contribute to making it a successful approach to IPPS	
NIPPS-P	The data that explain the relationship between the success of IPPS and proposed method of identifying, selecting and engaging participants who will be involved in the IPPS process
NIPPS-CE	The data that can assess the value of creating conceptual environment for the success of IPPS meetings
NIPPS-T	The data that can assess the role of communication technologies in the IPPS process when EC-FIKT is applied
NIPPS-PS	The data that are required to assess the effectiveness of knowledge created at IPPS projects
NIPPS-O	The data that include the outcomes brought to the manufacturing companies and the individuals involved by applying the EC-FIKT for running a IPPS project
EVAL	The data that assist evaluating the process of IPPS, based on the experience of applying EC-FIKT

Once the list of codes was developed, the researcher analysed all the data collected such as field notes, e-mail communications, notes from open-ended interviews, observation and notes from IPPS meetings. For every relevant piece of data, the codes described in Table 6-2 were embedded in the original text.

The data condensing and transforming process assisted the development of pattern codes that are the focus of the next stage of the process presented in this chapter.

6.2.3. Second cycle coding: pattern codes

The first cycle coding, described in section 6.2.2 assisted the researcher to summarise segments of data from specific documents which were produced during the data collection process. in order to create smaller number of ideas or themes to represent the perception of more than one individual, it was essential to group the results of first cycle codes. Miles *et al.* (2014) refers to this process as pattern coding which helps qualitative researchers to identify an emergent theme through pulling together a lot of material from first cycle coding into more meaningful units of analysis. Auerbach and Silverstein (2003) refers to theme as an implicit topic that organises a group of repeating ideas.

In order to identify pattern codes, the researcher condensed the data that resulted from the first level coding using a smaller number of concepts that could be mentally stored and readily retrieved. These concepts, which synthesise the sets of concepts that were originally defined in Table 6-1 and Table 6-2 during the first cycle coding, are included in Table 6-3.

Table 6-3. The concepts that were employed during the second cycle coding of data collected throughout the multiple case study

Code	Definition of code	Definition of data
I. EC-FIKT approach	The implementation of IPPS based on effective intra-organisational communication	Group of data that assist this research to investigate whether the EC-FIKT approach as defined in chapter four of this thesis is successful in effectively engaging diverse functions in IPPS
II. Other approaches	The limitations of existing approaches to IPPS in comparison with the application of EC-FIKT	Group of data that assists this research to understand the extent to which EC-FIKT reduces the limitations of other approaches to IPPS
III. Group dynamics	EC-FIKT and leading group dynamics	Group of data that assists this research to understand the extent to which the success of EC-FIKT in effectively identifying and engaging individuals from diverse functions in solving complex problems is related to the nature of the IPPS team and the leadership of its group dynamics
IV. Evaluation	Evaluation of EC-FIKT as an approach to IPPS	Group of data that assists this research to understand how the application of EC-FIKT was evaluated and whether such an approach to evaluation was successful

Data condensation in the second cycle coding assisted this research in grouping the frequent facts in the process of the implementation of EC-FIKT in different manufacturing companies, or frequent phrases in field notes, open-ended interviews, Skype meetings and other data that had been coded through first cycle coding. These repeating themes were extracted from the data collected and presented in a number of tables.

The researcher employed presentation of the data in table format to address the limitations of purely text-based evidence. Moreover, presentation of the data in table format allows focused display that will permit simultaneous viewing of a full data set derived from multiple case study. This method assisted the researcher to draw conclusions that answer the research questions and it is intended to assist the reader to clearly understands the origin of such conclusions. The use of tables is supported by the researcher's experience in using different visual representation schemes as an aid to conveying knowledge that could otherwise be difficult to understand.

The second cycle analysis of data collected during the application of EC-FIKT at SMcorp is included in Table 6-4. A similar analysis for data collected during the application of EC-FIKT at CPG Ltd is included in appendix B.

Table 6-4. Key ideas and themes from the IPPS project at SMcorp

I. EC-FIKT approach. The implementation of IPPS based on facilitated information and knowledge transfer	
A. Outcomes of the application of EC-FIKT	The outcomes that were identified by individuals can be grouped into four key categories that are as follows: 1. Learning by experts All the experts mentioned that EC-FIKT helped them to review the information resources that is available at their manufacturing company and learn about the data and information that they need is available at which functions and how they can access and use these resources as a very reliable alternative to creating and developing them within their departments. Examples of these ideas are as follows: *It helped us to recall the resources we have* *It showed that other functions already have the data chunks that we have been investing on producing* *I did not know (one of the functions) has been collecting such data that we can access. It really helps our department to prevent duplicating other function's work and instead develop a better work together* 2. Learning by departments All the participants from diverse functions agreed that EC-FIKT helped them to understand what delay on the shop floor means to each part of the production line and it helped them to understand that all the functions are very much concerned about improving the performance of SMcorp and have been investing on addressing this issue. It helped them recognise the importance of combining experience of different functions for investigating delay-related issues and developing a reliable solution. Examples of these ideas are as follows: *The discussions highlighted the need for involving experts from different functions and now I can consider the outcome of these meeting as a benefit for my company* *We (one of the functions) have been looking for that information for a long time* *This information will reduce the amount of time my team were spending on analysing delays data* 3. New explicit resources became available Several data models were developed, reviewed and revised by the participants which became a valuable resource for all the functions involved in the IPPS project. Example of senior manager comment about these data models is as follows: *It will help us to map the cause and effect quicker and also we can use these models to identify the units that needs improvement*

Table 6-4. Key ideas and themes from the IPPS project at SMcorp

	4. New communities of interest Participants agreed that the way EC-FIKT helped them to have a cleared picture of the problem and the factors influencing the problem could not be achieved without such meetings that involved many areas of problem-related experience. Two of the comments are as follows: *I would need to send and receive many e-mails to solve the issue that is addressed this quickly by the help of many expert' gathered today* *I found the 'credible problem resolution' part of the process very important and helpful*
B. Mapping the root causes of the complex problem	The participants agreed that the developed data models during IPPS meetings (the design-shop) helped them to understand the influence of their work on the work of other functions and delays on the shop floor in general. They found this facilitated information and knowledge transfer a successful approach that involves all the functions who are influenced by or have influence on the performance of other functions to solve the problem together. Some of their comments are as follows: *This process improved my understanding about the relationship between individual functions' performance and the performance of the SMcorp* *The data models clarified how the delay on the shop floor is altered or affected by work of different functions*
C. Participants	Once the required information and knowledge resources were identified, the potential functions and individuals were identified. Experts from SMcorp selected potential participants from different functions within this manufacturing company based on three principles that are as follows: 1. Managers with significant problem-centred knowledge and experience in dealing with delay-related issues 2. Managers from functions that hold delay-related data and information 3. Senior manager from the function which its performance had been influenced by delay-related issues
D. Type of information and knowledge	Information and knowledge related to root causes of delays on the shop floor was successfully presented and contributed to problem-solving
E. Communication technologies	It became evident that information system can only assist data/information transfer and it does not improve the process of engaging skills and experience from diverse functions in solving complex problems.
II. Other approaches. The limitations of existing approaches to IPPS in comparison with the application of EC-FIKT	
A. Demands from participants	Although it was not possible to compensate for participants' time, this project contributed to the performance of the SMcorp functions and overall performance of this manufacturing company.
B. Collaborative environment	Notes taken by the researcher during and after the IPPS meetings show that: 1. The IPPS meetings took place in a relaxed, informal environment that helped experts to contribute their knowledge however they

Table 6-4. Key ideas and themes from the IPPS project at SMcorp

	found it easier to do, e.g. through the use of examples, comparing the limitations of their individual function's approaches to understanding and addressing delay-related issues 2. There is no evidence that suggests that any of the experts found it difficult to contribute their perception on the topics discussed.
C. Motivation	Data collected show that experts from different functions were motivated to actively participate in the IPPS project for different reasons that are as follows: 1. The purpose of the collaboration. Findings the root causes of delay-related issues affecting the performance of SMcorp, in particular in terms of energy consumption, had been a complex problem and addressing them had been the concern of all the functions 2. The performance of some of the functions were challenged by the performance of SMcorp and participating in the IPPS could create an environment to discuss this issue 3. It could raise awareness about the area of work of different functions and how each of them could benefit from facilitated information and knowledge transfer
III. Group dynamics. EC-FIKT and leading group dynamics	
A. Trust	Evidence shows that clarifying the purpose of the IPPS meetings leaded the participants to openly contribute their knowledge and experience
B. Communication	The observation and notes taken during the IPPS meetings show that participation was not restricted to experts' contributions in any of the IPPS meetings. Participants contributed actively to the discussions, even when it was only to raise questions and concerns in the search for experts' answers and support
C. The role of leader(s)	The data collected highlight that leading the IPPS meetings by the researcher and IKT research expert had positive impact on addressing departmental boundaries and directing participants to focus on effective communication and problem-solving. It also shows the importance of including expert from SMcorp as IPPS leader who had significant positive influence on leading the participants in terms of contributing to problem-solving when participants were distracted by sharing some of their knowledge and experience which were irrelevant to addressing the problem.
IV. Evaluation. Evaluation of EC-FIKT as an approach to IPPS	
The IPPS project was evaluated based on getting feedback from the participants immediately after the IPPS meetings which were mostly during the breaks of the design-shop by asking participants about the impact of the meetings on their understanding of the problem and about the value of the knowledge created through EC-FIKT for their manufacturing company. The comments were generally positive, in particular about the collaboratively developed data models. Managers from SMcorp, in particular, found this project a successful collaboration.	

Once relevant themes and frequent ideas for each individual case had been extracted, the analysis moved on to analyse those patterns that were valid across the cases in the multiple case study. This process was based on the same codes that were employed for the second cycle coding, presented in Table 6-4.

Based on the concepts included in Table 6-4, Table 6-5 presents collection of the main ideas and themes that resulted from cross case analysis of the data collected.

Table 6-5. Cross-case analysis: key ideas and themes

I. EC-FIKT approach. The implementation of IPPS based on felicitated information and knowledge transfer	
A. Outcomes of the application of EC-FIKT	EC-FIKT successfully involved all the participants in IPPS projects, regardless of their profession or their lever of skills and expertise, in the information and knowledge transfer activity. It became evident that identifying and engaging individuals with problem-centred knowledge is more important to focus on in comparison with relying on area of expertise. The application of EC-FIKT resulted in producing displays of factors influencing the problem and network models that presents the relationship between root causes of the complex problem which were significantly useful for the manufacturing companies involved in IPPS projects. The application of EC-FIKT contributed to business performance of SMcorp which is one of the largest manufacturing companies in Nigeria. The application of EC-FIKT at CPG Ltd contributed to the development of a new method for understanding cause and effect of production waste which has important value for this manufacturing company in Nigeria.
B. Mapping the root causes of the complex problem	In particular, for solving process-related problems which are complex and more difficult to specify in comparison with product-related problems, the process of mapping the root causes of the problem significantly helped the manufacturing companies in term of addressing complex problems. Mapping the root causes of the problem also helped the participants to better understand the problem domain and contribute to effective communication across departmental boundaries.
C. Participants	EC-FIKT, considerably, identifies the importance of engaging the right people in the process of identifying, selecting and engaging the right participants for IPPS. The involvement of experts from the involved manufacturing companies in the project initiation and project preparation, the first phase of EC-FIKT, significantly contributed to the success of its application.
D. Type of information and knowledge	This new approach to IPPS successfully involved individuals with problem-centred information and knowledge which included individuals from the functions that have influence on the problem, the functions that are affected by the problem and functions that have experience about solving complex problems in specific manufacturing companies.
E. Communication technologies	Although information technologies helped the IPPS project in terms of communication in virtual environments such as Skype, it only proved its

Table 6-5. Cross-case analysis: key ideas and themes

	value for data/information transfer.
II. Other approaches. The limitations of existing approaches to IPPS in comparison with the application of EC-FIKT	
A. Demands from participants	The implementation of EC-FIKT only required participation in IPPS meetings. The manufacturing companies involved, were willing to allow experts to participate in IPPS meetings for the reason that these meetings were necessary for addressing their complex problems. There is no evidence to suggest that this demand had a negative influence on the integration of process planning and scheduling.
B. Collaborative environment	No evidence was collected that suggest any of the participants found it difficult to contribute their knowledge during the IPPS meetings.
C. Motivation	EC-FIKT assists the participants in understanding the purpose of IPPS project and, more importantly, assists them in creating credible problem resolution. These characteristics significantly motivated the participants to freely express their perceptions and contribute to problem-solving.
III. Group dynamics. EC-FIKT and leading group dynamics	
A. Trust	Trust was identified as an issue at the initial stage of the development of EC-FIKT. This issue was clearly identified and become one of the key steps of EC-FIKT. Evidence shows that clarifying the purpose of the IPPS meetings leaded the participants to openly contribute their knowledge and experience.
B. Communication	Evidence shows that all the participating individuals in applications of EC-FIKT made a significant contribution to problem-solving.
C. The role of leader(s)	In some cases, involving leader(s) from the area of IKT management and leader(s) with problem-related experience make the application of EC-FIKT more feasible. The IPPS leader from SMcorp significantly helped the process of selecting experts and inviting them to engage in IPPS meetings. Moreover, the number of the functions involved in CPG Ltd project, complexity of the problem and lack of the researcher's experience in running such IPPS meetings proved that involving skilled IKT leader and an expert who has enough problem-related knowledge is essential for the effective IPPS meetings.
IV. Evaluation. Evaluation of EC-FIKT as an approach to IPPS EC-FIKT was evaluated, in most cases, by getting feedback from the participants. These feedbacks were collected after the IPPS meetings to capture the perception of the participants about the value of what they achieved through IPPS on the critical success factors of their manufacturing companies.	

6.2.4. Theoretical constructs

The researcher significantly summarised the data collected that emerged across the multiple case study to group of patterns and tried to generalise these findings through developing a series of theoretical constructs.

Auerbach and Silverstein (2003, p.69) affirm that the procedure for creating theoretical constructs from themes has the same form as the procedure for creating themes from repeating ideas. They explain that theoretical construct consists of grouping of themes and ideas into abstract ideas consistent with the theoretical structure of the research. Miles et al. (2014) remark that developing theoretical constructs facilitates creating conceptual level from empirical data.

The researcher developed a number of theoretical constructs from the cross-case data analysis carried out in this section. The results of the cross-case data analysis as presented in Table 6-5 became essential for justifying the building of theory from the data collected. Using as an example the value of models as an additional outcome of the implementation of EC-FIKT, Table 6-6 shows the process of building a theoretical construct using the data collected across the multiple case study.

Table 6-6. Building a theoretical construct: The models resulting from the implementation of EC-FIKT

Organisation	**Results of the data analysis**	**Theoretical construct**
SMcorp	Series of models developed became an important explicit resource for this manufacturing company. These displays clearly illustrated the factors influencing delays on the shop floor, the importance of each factor, the relationship between different factors and also expert's suggestions for process improvement. Series of network models developed became an important tool for mapping the poor information and knowledge channels between different functions of SMcorp.	In addition to effective IPPS, running EC-FIKT approach is likely to bring other benefits to the manufacturing companies involved, including models of different aspects of the problem domain. Such models might become an explicit source of information and knowledge for reference by the manufacturing companies.
CPG Ltd	Series of data models developed became an important tool for the CPG Ltd as it could be used to map cause and effect of production waste. It also could be further developed or reduced based on the user's requirements in investigating specific waste-related issue.	

Following a process similar to the one outlined in Table 6-6, the theoretical constructs (TC) were built that are as follows:

TC.1. In the conditions of the manufacturing companies involved in this research, face-to-face, led by collaborative leader and collaborative mapping of root causes of complex problems is a valid approach to IPPS

TC.2. EC-FIKT is a valid approach for implementing collaborative problem-solving that is based on face-to-face, led by collaborative leader(s) and collaborative mapping of the complex problems

TC.3. In addition to the collaborative problem-solving, running EC-FIKT has the potential to bring other benefits to manufacturing companies involved such as outcomes which may become an explicit source of information and knowledge for reference by the manufacturing companies

TC.4. IPPS projects are more likely to be successful if they have a clearly defined focus. The manufacturing company has an important role to play in identifying and selecting potential participants and also motivating those potential participants to accept to participate in IPPS meetings

TC.5. EC-FIKT has been perceived as a successful approach to collaborative problem-solving by the manufacturing companies involved in IPPS projects

TC.6. Communication technology is not a necessity for the success of collaborative problem-solving

TC.7. Based on the experience of the manufacturing companies involved in the multiple case study there is no evidence that suggests that the demands of implementing EC-FIKT have a negative effect in maintaining its purpose

TC.8. The data collected show that individuals involved in collaborative problem-solving using EC-FIKT feel motivated to contribute their knowledge and learn from other participants. EC-FIKT supports and values freely communicating participants' perceptions of the problem and collaboratively developing credible problem resolution. Creating credible problem resolution without encountering significant disagreement between stakeholders requires addressing the complexities associated with limited sense of shared characteristics and common knowledge between the participants

TC.9. IPPS leader(s) have key role in the success of a IPPS meetings based on the implementation of EC-FIKT. The role of IPPS leader(s) is one of co-ordinating and supporting the process by which participants create knowledge and solve problems

TC.10. The success of EC-FIKT as an approach to IPPS can be assessed by exploring the alignment of its outcomes with the critical success factors of the manufacturing company as perceived by it

6.3. Drawing and verifying conclusions

At this stage the evidence collected in order to answer the research questions has been substantially summarised and basic theory, consistent with the theoretical framework of the research, has been built. This work has prepared the way for the drawing and verifying the conclusions of the data analysis.

6.3.1. Drawing the conclusions

Dealing with the secondary research questions

The theoretical constructs built and represented in section in section 6.2.4 became important tool in the process of drawing the conclusions of the multiple case study. Many of the constructs represented in themselves part of the answer to the secondary research questions that led this research, which were outlined in chapter one, that are as follows:

RQ.1. What does the concept of integration of process planning and scheduling mean?

RQ.2. What is the relationship between manufacturing productivity and integration of process planning and scheduling?

RQ.3. What is the relationship between group dynamics and success of integration of process planning and scheduling?

RQ.4. What is the role of technology in the process of integration of process planning and scheduling?

RQ.5. How can effectiveness and success of the integration of process planning and scheduling be assessed?

In addition to the theoretical construct there were two other key sources of input to answer the secondary research questions. These sources of input were as follows:

- The findings of the literature review, presented in chapter three of this thesis

- The development and refinement of EC-FIKT during the field research that are described in chapter four of this thesis

The process of addressing the secondary research questions, at least partially, using these key sources of input is shown in Table 6-7.

Table 6-7. The process of addressing the secondary research questions

Secondary research question	Sources that contribute to the answer
RQ.1	Literature review, field research, TC-8, TC-9, TC-10
RQ.2	Literature review, field research, TC.1, TC.2, TC.4, TC.6, TC.9
RQ.3	Literature review, field research, TC.3, TC.9
RQ.4	Literature review, field research, TC.6
RQ.5	Literature review, field research, TC.10

Dealing with the primary research question

The primary research question had been defined in chapter one that is as follows:

> *How do we minimise the limitations to existing manufacturing approaches which integrate process planning and scheduling in developing countries?*

It is mentioned in chapter one how the secondary research questions derived from the primary research question. As a result, it was found during the data analysis that answers to each of the secondary research questions contributed to the answer of the primary research question.

In order to address the primary research question, the following conclusions were drawn based on the assessments from participants in the multiple case study as it has been described in this chapter:

1. EC-FIKT is a valid approach to engaging diverse functions in collaborative problem solving
2. EC-FIKT is a successful approach for the implementation IPPS
3. EC-FIKT reduces some of the key limitations of existing approaches to IPPS

Table 6-8 is intended to assist the reader to understand the extent to which the data collected shows that EC-FIKT reduces the limitations of existing approaches to IPPS. The analysis is based on the comparison of observed outcomes of EC-FIKT during the field research and known deficiencies of other approaches as identified in the review of the literature, chapter two of this thesis.

Table 6-8. The evidence that suggest EC-FIKT reduces the limitations of existing approaches to IPPS

Limitations of existing IPPS techniques	**IPPS approaches that face these limitations**	**Evidence that suggest EC-FIKT reduces these limitations**
The characteristics of the information and knowledge sought to be employed to contribute to problem-solving limit the success of IPPS techniques	The applicability of information and knowledge transfer limits the outputs of methods that were used within the field of information system The variety and complexity of the information and knowledge to be discussed limits success of the approaches applied to problem-solving within the fields of information system The perceived validity and quality of information and knowledge limits success of approached to IPPS within the field of supply chain management The rational, emotional and political issues that characterise the information and knowledge being discussed for the purpose of productivity affects the success of supply chain management as a productivity approach The psychological validity of the information and knowledge may impact success of the approaches applied in the field of lean manufacturing, as the newly created information and knowledge is not always likely to be applied The volume and issues related to the maintenance of information and knowledge stored in software affect the value of these as IKT tools	EC-FIKT has been successful in the problem-solving relating to different aspects of the manufacturing companies in developing countries activities and in different contexts. These included information and knowledge relating to areas that are as follows: - The process of investigating root causes of delays on delays shop floor at SMcorp - The process of interacting with functions that their performance is affected by delays on the shop floor at SMcorp - The process of investigating the factors causing extra energy consumption at CPG Ltd - The process of investigating factors influencing the work performance of different functions within CPG Ltd - The process of communicating production waste-related data between different functions within CPG Ltd The data collected highlights that individuals and manufacturing companies involved were ready to apply the newly created solution immediately after the IPPS projects
The significant demands that the IPPS processes impose on participants	The time and skills required to describe information and knowledge in a structured way and add information on the context of the specific experience limited success of the approaches used within the field of information systems to engage individuals in contributing their knowledge The complex patterns of interaction among analysts and individuals who have the	Based on the experience of the manufacturing companies involved in the multiple case study, implementing EC-FIKT involved a number of staff for relatively short periods of time The analysis of discussions held during the IPPS sessions would potentially yield additional results It is acknowledged that such an analysis would require a significant amount of additional time.

Table 6-8. The evidence that suggest EC-FIKT reduces the limitations of existing approaches to IPPS

Limitations of existing IPPS techniques	**IPPS approaches that face these limitations**	**Evidence that suggest EC-FIKT reduces these limitations**
	knowledge during the problem-solving process affects success of the approaches applied within the field of information systems Time, skills and resources required by experts to contribute knowledge, and time and effort required by functions affect the success of methods applied within the field of operations management The stresses and demands that a lean manufacturing project can impose on participants could limit success of the problem-solving approach to productivity As within the MS field, the use of communication technologies for problem-solving is affected by the time, skills and effort required from the individuals involved	However, data collected suggests that manufacturing companies were satisfied with the direct outcomes of the IPPS project
Problems related to the selection of experts and their ability to contribute their information and knowledge	productivity approaches used in the fields of information system and lean manufacturing were affected by relying on the views of a single expert as they were unable to reconcile different and sometimes conflicting views The potential difficulties in identifying experts in the workplace affects the methods applied to IPPS within the field of information systems Lean manufacturing projects are affected by what has been termed 'the expert solution': when experts are part of the problem-solving groups, members look to them for solutions rather than collaboratively solve problems	EC-FIKT is a structured process that relies on the manufacturing company's awareness of its needs to involve specific information and knowledge resources and create knowledge by specific individuals. It does not include a stage or guidelines concerned with the selection of participants. Instead, it understands that the manufacturing company itself has the best possible view of the experience of its employees and is therefore in the best position to appoint those that will participate as experts. Although this may still be considered as a limitation, EC-FIKT offers an alternative view to some of the existing techniques that rely on expertise spontaneously emerging from unknown organisational sources Once the team of IPPS participants has been formed, the structure of the approach, the nature of the collaborative mapping of root causes of complex problem and the leadership techniques applied seek

Table 6-8. The evidence that suggest EC-FIKT reduces the limitations of existing approaches to IPPS

Limitations of existing IPPS techniques	**IPPS approaches that face these limitations**	**Evidence that suggest EC-FIKT reduces these limitations**
		to elaborate the experts' contributions Evidence collected during the field research shows that most experts have been able to contribute their knowledge throughout the different stages of each of the IPPS project The method helps the participants to create a credible problem resolution which eliminates the problem of conflicts of perceptions among them
Motivational issues related to engaging potential participants in IPPS	How to motivate individuals to contribute their knowledge has been one of the most important issues to resolve in most fields that have relied on collaborative problem-solving, such as the field of operations management. Similarly, users of the knowledge newly created by experts often refuse to apply it due to a number of reasons In particular, within fields such as information system failure has been related to the fact that individuals are often restrained by their motivation when striving to express, apply, and explain their knowledge	Based on the evidence collected throughout the field research, all participants in each of the applications of EC-FIKT were significantly motivated to share their experience and collaboratively solve problems, and all of them would recommend others to participate in similar projects The data collected shows that during each IPPS meeting, experts contributed to problem-solving. Experts also asked and were willing to learn from others doing, for example, different types of work As for functions, data collected show that in most cases they found it useful to have the opportunity to discuss issues directly with the experts (which also contributes to the assessment of the approach to selecting the experts).

The conclusions of this research, which address the primary research question, have been derived from the clustering of the theoretical constructs included in Table 6-9. While doing this, the researcher required to ensure that there was enough evidence in the data collected to support each conclusion. Thus the conclusions drawn would not only be conceptually coherent but also supported by the perception of participants in the multiple case study.

Table 6-9. Drawing conclusions: The clustering of theoretical constructs

Theoretical constructs	Resulting conclusions
TC.1. In the conditions of the manufacturing companies involved in this research, face-to-face, led by collaborative leader and collaborative mapping of root causes of complex problems is a valid approach to IPPS TC.2. EC-FIKT is a valid approach for implementing collaborative problem-solving that is based on face-to-face, led by collaborative leader(s) and collaborative mapping of the complex problems TC.3. In addition to the collaborative problem-solving, running EC-FIKT has the potential to bring other benefits to manufacturing companies involved such as outcomes which may become an explicit source of information and knowledge for reference by the manufacturing companies TC.4. IPPS projects are more likely to be successful if they have a clearly defined focus. The manufacturing company has an important role to play in identifying and selecting potential participants and also motivating those potential participants to accept to participate in IPPS meetings TC.5. EC-FIKT has been perceived as a successful approach to collaborative problem-solving by the manufacturing companies involved in IPPS projects TC.6. Communication technology is not a necessity for the success of collaborative problem-solving TC.9. IPPS leader(s) have key role in the success of a IPPS meetings based on the implementation of EC-FIKT. The role of IPPS leader(s) is one of co-ordinating and supporting the process by which participants create knowledge and solve problems	Conclusion 1: Face-to-face, led by collaborative leader and collaborative mapping of root causes of complex problems is a valid approach to engaging diverse stakeholder groups in IPPS Conclusion 2: EC-FIKT is a successful method for the implementation of face-to-face, let IPPS through collaborative mapping of root causes of complex problems
TC.4. IPPS projects are more likely to be successful if they have a clearly defined focus. The manufacturing company has an important role to play in identifying and selecting potential participants and also motivating those potential participants to accept to participate in IPPS meetings TC.5. EC-FIKT has been perceived as a successful approach to collaborative problem-solving by the manufacturing companies involved in IPPS projects TC.7. Based on the experience of the manufacturing companies involved in the multiple case study there is no evidence that suggests that the demands of implementing EC-FIKT have a negative effect in maintaining its purpose TC.8. The data collected show that individuals involved in collaborative problem-solving using EC-FIKT feel motivated to contribute their knowledge and learn from other participants. EC-FIKT supports and values freely communicating participants' perceptions of the problem and collaboratively developing credible problem resolution. Creating credible problem resolution without encountering significant disagreement between stakeholders requires addressing the complexities associated with limited sense of shared characteristics and common knowledge between the participants	Conclusion 3: EC-FIKT reduces some of the key limitations of existing approaches to integration of process planning and scheduling

6.3.2. Verifying the conclusions

Meaning has been generated from a large set of data. The findings of the research have been interpreted. A large section of this chapter has focused on describing how the researcher arrived at such findings. However, actions were taken during the final stage of the data analysis to confirm the findings in order to address an issue that affects qualitative research: the validity of conclusions.

There are many different tactics for testing or confirming the findings of qualitative research. These include, weighting the evidence, using extreme cases, looking for negative evidence and many others (Miles *et al.*2014). Most of these have as their ultimate aim addressing concepts such as the representativeness, reliability and replicability of the findings. A review of the different approaches that exist is beyond the scope of this section.

There are no agreed-upon mechanisms to indicate whether findings of qualitative research are valid and procedures are robust (Miles *et al.*, 2014; Yin, 2014). Therefore, the researcher followed a process that has been classified by Miles *et al.* (2014; p. 309) as *one of the most logical sources of corroboration* that is getting feedback from participants. They emphasise that participants' evaluation of the research findings is one of the most logical and reliable tactics for confirming findings.

The researcher included some of the feedbacks he received after conducting the IPPS meetings, throughout the multiple case study, in relevant part of this thesis. The key points included in feedbacks from SMcorp in regards to verifying the conclusions are as follows:

- *It supported SMcorp in development of a fledgling programme designed to drive actionable insight from employees' experience. The goal was to turn the wealth of knowledge in actions that would drive improvements in energy consumption on the shop floor*
- *It helped SMcorp to understand the gap in its analytics capabilities*
- *It provided SMcorp with a solution to drive new localised short term improvements to deliver small but rapid change*

The assessment of some of the participants from CPG Ltd project identified some benefits of these collaborations that are as follows:

- *It developed tools that supports CPG Ltd in its efforts to understanding the potential root causes of some of the production waste*

- *The functions participated in the design-shop found this collaboration the start point of realising how different groups within the CPG Ltd are working on very similar problems associated with production waste, in total unawareness of each other.*

These perceptions of the manufacturing companies involved in this research represents their understanding of the finding of this research and maintain confirming findings. The researcher considered that these views were representative of the perception of the manufacturing companies involved in this research, and therefore the conclusions presented in this chapter are considered valid. With this step, the data analysis was concluded.

6.4. Summary

This chapter has described in detail how the data collected during the field research was analysed. The body of data collected as a result of the implementation of a multiple case study was reduced to manageable contents that were then displayed using tables. Data were analysed for every individual application of EC-FIKT. This was then followed by a cross-case analysis. Theoretical constructs were derived from the analysis. Some of these, in conjunction with the findings of the literature review and the field research, provided answers to one or more of the secondary research questions that drove this research. The conclusions of the field research, which address the primary research question, were drawn from those theoretical constructs. This chapter also described how the validity of the conclusions drawn from the data collected was assessed.

Chapter seven will discuss the main issues that emerged from this research and also analyse the areas that will benefit from further research.

7. Discussion and further research

This chapter includes summary of the results of this research. It covers the overview of the path taken in this research followed by discussion of its primary contributions. It describes the limitations of research conducted and suggests areas for further research.

7.1. Overview of the path followed in the conduct of this research

The collaboration between the researcher and SMcorp introduced the potential demand for new approach to integration of process planning and scheduling in manufacturing companies in Nigeria. This collaboration provided the drive for developing a new generic question, how to identify individuals and functions within a concerned manufacturing company that have problem-centred knowledge and how to successfully engage them in effective information and knowledge transfer? The review of the literature explained the tangible and intangible problems that hinders the success of existing approaches to involving different functions of a manufacturing company in intra-organisational information and knowledge transfer. This motivated the researcher to formulate a more precise primary research question that is as follows: *How do we minimise the limitations to existing manufacturing approaches which integrate process planning and scheduling in developing countries?* The analysis of this primary research question was followed by identifying a number of secondary research questions and a conceptual framework which defined the scope within which the issues related to integration of process planning and scheduling was to be studied by this research.

The next parts of this research revolved around development of the new approach based on the implementation of IPPS projects with different manufacturing companies in Nigeria. The specific dimensions of this new approach were developed through employing the lessons learned from the collaboration with SMcorp. The researcher called this new method Effective Communication through Facilitated Information and Knowledge Transfer (EC-FIKT) which was developed as practical process of collaborative leadership for implementing successful IPPS. In subsequent stages of this research, the analysis was based on comparing the limitations of existing approaches to IPPS that were identified and reviewed in the relevant literature review reported in the body of this thesis with the empirical findings of the implementation of EC-FIKT in different manufacturing companies.

The factors that has been driven the path taken in this research can be described in three key areas that are as follows:

- The need for involving functions and individuals that are affected by the problem, functions and individuals that have influence on the problem and individuals who have problem-centred knowledge in IPPS process
- The need for a new approach that addresses limitations of existing approaches to IPPS
- The success of a new information and knowledge transfer approach to IPPS based on collaborative leadership

7.2. Key contributions of this research

The new approach to IPPS is the lead in identifying the original contribution of this research that is the answer to the primary research question of this research. The practical process of the new approach to IPPS projects, reported in this research, suggests that it has certain advantages over the existing approaches. In addition to the original contribution of this research, this research contributed to success of a key manufacturing companies, in Nigeria, in solving complex problems. This section will review these contributions in some details.

7.2.1. Contribution to the body of knowledge in the field of IPPS

A successful approach to information and knowledge transfer in IPPS has been developed, refined and validated in the field. This approach addresses the challenges associated to identifying, selecting and effectively engaging individual who have problem-centred in IPPS which comprises the key to reducing the identified limitations of existing other approaches.

In order to clarify the process of applying this new approach to IPPS in practice, this research designed Effective communication through facilitated information and knowledge transfer approach which defines a lead-in steps that manufacturing companies can run.

For the development of EC-FIKT, it was essential to review the main areas that indicated negative impact of IPPS limitations on their applications. This thesis included this review that comprised a summary of the benefits and limitations of existing approaches to IPPS in different fields including information systems, operations management, lean manufacturing, supply chain management and collaborative leadership. The results of such a review become an additional contribution to the body of knowledge in the field of integration of process planning and scheduling.

Identified limitations of existing approaches to IPPS and the findings resulted from the applications of the new approach in the field verifies that the new approach has been successful in some significant areas that are as follows:

- It encourages effective collaboration between members of different functions within a manufacturing company beyond the conventional function's works
- It addresses the challenges associated with communication between individuals or functions across departmental boundaries
- It revolves around involving individuals who have problem-centred knowledge without being concerned about their skill or expertise but their experience
- It involves individuals and functions that are affected by the problem in addition to involving individuals and functions who have influence on the problem
- It creates conceptual environment that enables effective problem-centred information and knowledge transfer across the departmental boundaries
- It provides an environment that engages diverse functions of a manufacturing company to contribute to problem-solving

7.2.2. Contribution to the success of the manufacturing companies involved in this research

The collaborative projects with manufacturing companies, in Nigeria, were successfully completed throughout this research. These collaborations that formed the multiple-case study in this research are follows:

- SMcorp. SMcorp is one of the key manufacturing companies in Nigeria
- CPG Ltd. CPG Ltd is one of the key firms within the Nigeria's manufacturing industry

The assessment of some of the participants from these two manufacturing companies identified some benefits of these collaborations, in addition to the primary benefits of IPPS, that are as follows:

- *It helped SMcorp to understand the gap in its analytics capabilities*
- *It developed tools that supports the CPG Ltd in their efforts to understanding the potential root causes of some of the waste-related events*

7.3. Limitations of the research

The two broad issues that determine the limitations of this research are as follows:

- The characteristics of IPPS domain
- The practicalities of the implementation of IPPS projects

7.3.1. The characteristics of IPPS domain

Process planning and scheduling has been addressed by this research as two interconnected processes that are related to transferring, sharing, and evaluation of knowledge towards creation of new solutions. Moreover, the definition of knowledge in the literature varies from one author to another; some authors consider knowledge and information as one concept and some authors consider knowledge and experience as one concept. The same principle applies to the definitions of expert and experienced. Therefore, understanding the meaning of each of these concepts and patterns of studying them is a challenging work.

During the implementation of this research, it became evident that the human nature of knowledge and experience creates the challenges associate with identifying individuals with problem-centred knowledge, individuals' willingness to share their knowledge with others, describing one's knowledge to others, motivating them to engage in collaboration and assisting them to contribute to problem-solving. In terms of describing one's knowledge to others, for example, diverse characteristics of internal and external individuals – individuals from one particular function and individuals from different functions – add to the difficulty of information and knowledge transfer between different functions or groups within one function, for example at departmental boundary – between different functions of SMcorp – one function found other function's problem too complicated to understand. However, these issues had less adverse effect during the SMcorp project than the CPG Ltd project with diverse characteristics of individuals from more than functions.

Additionally, lack of common knowledge between the researcher and different functions of the manufacturing companies creates additional boundary and spanning this boundary is time consuming and fails if the mutual understanding of the problem in hand does not take place at the early stages of collaboration.

The nature of IPPS research domain comprises a share of significant number of characteristics with other areas such as psychology and intra-organisational communication. The scope of this research could only allow a limited study of some of these characteristics that are as follows:

- Demographic characteristic

This research revolved around one specific demographic characteristic, in the implementation of IPPS projects, that is the level of problem-related experience and problem-centred knowledge of individuals. Issues related to other demographic characteristics such as age or gender of participant has not been studied in this research.

- Group dynamics

The significant impact of individuals' behaviours towards engagements in collaborations on the process of IPPS is inevitable. This research could address the issues related to the group dynamics to a limited extent through collaborative leadership. Moreover, there are issues related to collaborative leadership, itself, that also could be studied only to a limited extend. These include the process of identifying and selecting right number of leaders, evaluating their skills or experience and clarifying their role in the IPPS projects.

- Collaborations at intra-organisational levels

The researcher was aware of the issues related to facts such as organisational structure which has significant impact on individuals and groups actions and interactions within and across the functions of manufacturing companies that can determine the success of implementation of a IPPS project. However, the context of this research allowed the researcher to cover these issues only to a limited extent.

7.3.2. The practicalities of the implementation of IPPS projects

The nature of collaboration and intra-organisational communication leads the studies in these areas to take place in a real-life context which required accessing many sources of data, which are only available within functions, followed by collecting data from a range of documentary evidence, review of participants' qualitative text, discussions with participants, interviewing participants and observing the development of IPPS process by the researcher. The field research opportunity, although limited, supported the researcher to collect enough evidence to study the success of IPPS at organisational level during the collaboration with SMcorp. However, the number of individuals from different functions involved in CPG Ltd project conflicted with time and resources required to conduct additional IPPS project at each function before engaging them in company-wide IPPS. Therefore, the issues that bounded the

practicalities of the implementation of EC-FIKT at company level to be studied to a limited extent that are as follows:

- Diverse functions have different perception of the factors affecting the problem and they also have different understandings of desirable solution
- Individual functions focus on the factors affecting their function rather than the ones affecting their domain as one whole
- Managing the impact of conflicting priorities
- Moderating the impact of knowledge diffusion across departmental boundaries

It became evident for the researcher that applications of intra-organisational EC-FIKT would have positive impact for its further development and assessment.

7.4. Areas of further research

The researcher has identified two areas of opportunity for further work that are as follows:

1. The study of factors that are likely to influence the effectiveness and efficiency of the new approach to IPPS
2. The study of factors that are likely to influence the applicability of the new approach in other contexts

7.4.1. The effectiveness and efficiency of the new approach to IPPS

The new approach to IPPS would benefit from three groups of features that can address the limitations of the approach identified in this research. These groups of features are as follow:

- The relationship between demographic characteristics and success of the new approach to IPPS

  In addition to the participants' problem-centred knowledge, their other demographic characteristics such as their age and backgrounds could have different impacts on the implementation of the new approach to IPPS. Therefore, a new setting can include the effects of variety of demographic characteristics on the IPPS process. Consequently, including more specific criteria for selecting participants could add to the efficiency of the EC-FIKT.

- The relationship between group dynamics and success of the new approach to IPPS

The application of EC-FIKT at CPG Ltd showed that engaging different individuals from diverse functions proposed more challenges associated with managing group dynamics in terms of promoting trust among them and motivating them to contribute to problem-solving. Therefore, considering a more precise study of spanning departmental boundaries could add to the effectiveness of intra-organisational information and knowledge transfer.

– The unit of study and success of the new approach to IPPS

It is also important to further study the problems related to organisational factors that affect the success of the new approach. Some of the organisational factors are the level of support that individuals receive from the manufacturing company to participate in collaboration. Competition between functions of an organisation or between different individuals of one function could provide a new setting for the study of the success of EC-FIKT in terms of motivating individuals to contribute to the success of IPPS.

There are other important issues related to the organisations involved in the application of the new approach to IPPS that can be studied further which are as follows:

- The applications of EC-FIKT were conducted through university-industry collaborations and the area of research of the researcher had positive influence on the success of the new approach to IPPS. Moreover, the researcher dedicated significant time to familiarise himself with the participating manufacturing companies' area of work and he put every effort to learn about their problems' context. For that reason, altering the group who runs the IPPS projects could provide a new setting for the study of the success of EC-FIKT. The relationship between required management support from participating manufacturing companies and the success of IPPS could also be studied further
- The application of this approach employed face-to-face meetings for distributed individuals from different functions of manufacturing companies through people-based approach. The feasibility of two-way communication through virtual environments, for geographically distributed individuals from different stakeholder groups who are willing to participate in the collaboration but cannot be physically present at where IPPS takes place, could provide a new setting for the study of the success of EC-FIKT.

In addition to addressing these three key features, the application of the new approach to IPPS can benefit from further research in areas such as cost-benefit analysis.

7.4.2. The applicability of the new approach to IPPS in other contexts

The applications of the new approach to integration of process planning and scheduling involved different manufacturing companies and different functions within each manufacturing company that are as follows:

- SMcorp project involved one of the key manufacturing companies in Nigeria and its largest functions
- CPG Ltd project involved total of seven senior managers from diverse functions of this manufacturing company in addition to several individuals with problem-centred knowledge

All of the manufacturing companies involved in this research are from manufacturing industry within Nigeria. Altering this criterion for the application of EC-FIKT could provide a new setting for the study of the success of EC-FIKT.

7.5. Summary

This thesis has presented a successful research with specific benefits for a various range of manufacturing companies and has made a significant contribution to the body of knowledge in the field of manufacturing system. This research has meant an opportunity for the researcher to strengthen his academic identity and industrial experience which could lead him to complete more research in the future.

The beginning of this research revolved around addressing the complexity of the SMcorp problem where SMcorp was unclear about its delays' reason on the shop floor which motivated collaboration between the groups who are affected by the problem and who have influence on the problem through the development and application of Effective Communication through Facilitated Information and Knowledge Transfer. SMcorp found the collaborations with the researcher successful that provided it with actionable outcome. This research assisted the SMcorp to realise the potential of its information and knowledge base. SMcorp understood the value of its resources about delays on the shop floor which were available to the manufacturing company but had not been studied prior to this research. It also

understood that its functions are knowledge-intensive departments and how it could benefit from problem-centred knowledge of its employees to solve its complex problem.

The seven senior managers from CPG Ltd and the employees who participated in this research found this experience valuable for improving problem-solving and shifting the effort to finding valuable and more reliable solutions together with functions that are somehow related to the problem and are working on addressing it in isolation. Moreover, they clarified how this research helped them to became aware of the fact that the knowledge they essentially require in their process of reducing production waste is available in other functions and the fact that they can access this reliable resource. They also became aware of the significant value of mapping the factors that has key influence on the problem through collaboration with different functions that have accurate and reliable knowledge and experience.

The particular contribution of this research has been to design and test out a process to assist the process of engaging diverse functions in effective problem-solving. Initial trials have yielded good results and suggest that the new approach to IPPS has real value. In particular, it promotes problem-solving in a way which has not been through existing approaches. it involves a collaborative environment where the participants explore and experience problem-solving. This environment is open to concerned departments to meet on an equal basis and co-create solutions for difficult problems. All the functions, who have problem-centred knowledge or can assist other functions to better understand the problem and possible solutions, contribute to the success of the integration of process planning and scheduling. The full potential and implications of the approach have still to be explored.

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Appendix A

Primary data collected during IPPS collaborative projects at SMcorp and CPG Ltd

A1. SMcorp – Original data collected

A1.1. Project initiation

A1.1.1. Summary of the communications between initial members of IPPS team

Participants	Event	Type	Result
- The researcher - IKT expert from SMcorp - SMcorp representatives	Overview of the SMcorp problem about delays on the shop floor	Discussions	Understanding the problem and clarifying knowledge domain
- The researcher - IKT expert from SMcorp - SMcorp team representative	Reviewing of research opportunities	- Discussions - E-mails	Identifying available and right participants
- The researcher - IKT expert from SMcorp - SMcorp representative - Production supervisor - Production technician	Reviewing of SMcorp problem about high level of delays on the shop floor Reviewing SMcorp previous attempts to solve the problem	- Introductory meeting - The researcher's observation	Indenting the complexity of the problem Developing draft project proposal The researcher's field note about the complication of the interaction between the participants
- The researcher - IKT expert from SMcorp - SMcorp representative	Share and review of draft project proposals	- E-mails	Agreeing on the benefits of the project for the researcher and SMcorp
- The researcher - IKT research expert from CU	Developing project proposal	- Discussions - E-mails	Final project proposal
- The researcher - IKT expert from SMcorp - SMcorp representative	Reviewing final project proposal	- Discussions - E-mails	Identifying the required data and knowledge resources Verifying access to required data and knowledge resources

A1.2. Project preparation

A1.2.1. Open interview questions

1. What product(s) does your company manufacture?
2. What manufacturing processes does your company employ in manufacturing?
3. What informed the type of manufacturing process your company employed?
4. How does your company source for its raw materials?
5. Are the products of your manufacturing system an end product or a raw material to other products?
6. What are the inputs of your company's manufacturing/production system?
7. How does your company control the inputs of production by ensuring the right inputs are made?
8. How efficient and effective do your manufacturing processes utilize the inputs in terms of output?
9. How much of your inputs turn out as waste? How is this measured?
10. How much emphases do your company place on the quality of your products?
11. How does your company ensure that the required level of quality is met (control mechanism)?
12. What system is in place for detecting non-conforming products?
13. Does the quality of your product conform to internationally acceptable standard?
14. What type(s) of production process layout does your company employ?
15. What informed the type of manufacturing process layout your company employed?
16. Does your layout process save production time?
17. Does your manufacturing layout process favour machine idle time?
18. What measures are in place to minimize wastages of raw materials?
19. How much of the waste generated are put into reuse?

A1.2.2. Consent letter

Dear Participant;

A QUESTIONNAIRE SURVEY ON PROCESS PLANNING IN MANUFACTURING

I am a doctoral researcher at the University of. As a part of my programme I am carrying out a research titled "IMPROVING MANUFACTURING PRODUCTIVITY THROUGH IPROVED MANUFACTURING PROCESS PLANNING ACROSS ENGINEERING ORGANISATIONS IN NIGERIA". The intended outcome will a model that will help to improve manufacturing productivity in Nigeria through effective process planning and scheduling. A copy of this will be sent free to all participants. It is being undertaken under the supervision of the '…'

Completion of the attached questionnaire will take approximately 20 minutes, and all questions can be answered by following the simple instructions. Completion of the questionnaire is completely voluntary. ALL RESPONSES ARE ANONYMOUS, there are no correct or incorrect answers and respondents who take part will not be identifiable. If results of this study are published they will be a summary of all responses to ensure that your privacy is protected.

Should you choose to complete the questionnaire, please return it in the enclosed stamped self-addressed envelope by post. By returning the questionnaire in this manner YOUR ANONYMITY IS ENSURED, so please use no identifiable markings. Returning this questionnaire will be considered as your consent to participate in the survey.

Once completed a summary of results will be available at the conclusion of the academic year. If you wish to obtain a copy of these results, please provide your contact details. Please note that all data gathered for this research will be stored securely and destroyed after the dissertation has been submitted. My supervisor and I will be the only people who will have access to this data.

Thank you for taking time to consider this invitation and if you choose to participate in this research I would like to extend my personal gratitude; your contribution is greatly appreciated.

Yours Faithfully,

A1.2.3. Questionnaire

1.) Location……

2.) Position……..……

3.) Gender. Male [ ] Female [ ]

4.) Age ……..

5.) Years of Experience (a) 11-15 years [ ] (b) 16-20 years [ ] (c) 21 years and above [ ]

6.) What type of manufacturing/production system does your company engage in? (a) Jobbing production [ ] (b) Batch production [ ] (c) Mass production [ ]

7.) What type of plant/equipment layout does your company apply? (a) Fixed-Position layout [ ] (b) process or Functional layout[ ] (c) Product or line layout [ ] (d) Combination or group Layout [ ]

A number of statements relating to process planning have been presented in the table below, please answer to the best of your knowledge based on what happens in your company… (Complete this instruction). From the options given in the right panel, please show the extent to which you agree with the statement by ticking the correct column. Please select only one answer per question and note that there is no right or wrong answer.

Key: SA= Strongly agree (5), A=Agree (4), NA/D=Neither Agree nor Disagree (3)

D=Disagree (2), SD=Strongly disagree (1)

	Production Planning and scheduling	**SD**	**D**	**NA/D**	**A**	**SA**
1	There should be an identification of the purpose of the processes which may include the name, quantity and quality of the product to be produced.					
2	There should be list of operations making up the process, an enumeration of the operations to show their sequence and designation of the place where each operation is performed					
3	Specifications are needed to make each operation conform to the principles of interchangeable manufacture and quality control					
4	There should be specification of the methods, machines, tools and equipment to produce the required quantity and quality of the products.					
5	There should be specification of the methods, machines, tools and equipment to produce the required products at the lowest cost.					

	Production Planning and scheduling	**SD**	**D**	**NA/D**	**A**	**SA**
6	There is need for specification of performance expected from each operation, in the form of the estimated or standard cycle time per piece and output expected in a certain length of time.					
7	There is need for specification of performance expected from each operation relative of the capacity of the production equipment					
8	Requirements and conditions of the processes which may include the specifications of the finished products, the size and shapes are necessary.					
9	Requirements and conditions of the processes which may include the specifications of other properties of the raw materials and the quality to be produced is necessary.					
10	There should be provision for improvement on the specification; all specification must be clear and explicit					
11	The most practical and economical manufacturing methods must be determined					
12	The selection of the correct equipment is a necessity					
13	All operations required in the manufacture of a product should be combined and put in proper and best sequence.					
14	Plant layout should be such that eliminates machine idle time in relation to inputs and outputs of production					
	Improving Productivity in production					
15	Work-study; The best way of doing a job and the time taken to do it efficiently is necessity					
16	Work-study; Breaking down the job into its various elements and ensuring that all workers engaged in the job are trained to do it the best way					
17	A good design of production which helps in the economical and convenient manufacturing (designing for production) will minimize scrap (waste) and reduce the cost of production					
18	Cost of production can be reduced by efficient and economical utilization of all the inputs resources, eliminating all types of wastages.					
19	A good plant layout which may include material handling will result in lower cost of production and higher productivity.					
20	Market research should be carried out to determine the actual requirement of the product,					

	Production Planning and scheduling	**SD**	**D**	**NA/D**	**A**	**SA**
	assess popularity of the company's products, identify and tap new markets.					
21	Every company who believes in development and higher productivity should have a strong research and development (R&D) department.					
22	Quality control functions should include inspection of incoming and outgoing materials, parts and products, inspection of work in progress and prevention of poor quality by timely warnings.					
23	Inventory control is the life blood of a production system that endeavours to achieve a balance between two little inventory and two much inventory.					
24	Automation of machines so that it can work for a relatively long time without human intervention should be encouraged.					
25	The importance of human factor in production: It has been increasingly realized that the man behind the machine is more important than the machine itself as productivity will not be improved if the man is not efficient.					
	Optimisation of the process plant layout					
26	The entire space of the plant/equipment layout should be economically and effectively utilized					
27	The investment in equipment should be kept at the barest minimum					
28	The handling and transportation of materials should be minimum					
29	The flow of materials should be smooth and rapid					
30	The layout should be such that supervision is easy, simple and effective.					
31	The utilization of men and machines should be optimum					
32	The layout should ensure maintenance of equipment and control of production is easy.					
33	The layout should provide adequate safety, healthy and comfortable working condition to all employees.					
34	The layout should make for a flexibility of rearrangement of production flow process					
35	All process layout should have provisions for future expansion of the plant.					
	Controlling and Maintaining the quality of inputs and outputs					
36	The inputs of production should be regulated at					

	Production Planning and scheduling	**SD**	**D**	**NA/D**	**A**	**SA**
	all times.					
37	Inputs should be continuous regardless of the output obtained					
38	Generation of outputs should be geared towards efficient utilization of inputs					
39	Much emphases should not be placed by the company on the quality of turned out products					
40	Quality of your company's product should at all times conform with international acceptable standard					
41	Detected non-conforming products should still be accepted by the quality control personnel to reduce wastages.					
42	The right control mechanism should be put in place to ensure high quality of products					
43	Less effort should be made to minimize wastage of inputs.					
44	Economic order quantity is optional in terms of avoiding over inventory of input resources.					

A1.2.4. Summary of participants input meetings

Participants	Event	Type	Result
- The researcher - Experts from quality control, information and data consultant	Review of the factors influencing delays on the shop floor	- Open-ended interviews - Questionnaire	Identifying the general factors that might lead to specific delay-related problem which would result in complaint or general dissatisfaction on the shop floor
- The researcher - Inventory officer - Production technicians	Staff training	- The researcher's observation - Questionnaire	Identifying specific factors that lead to poor quality of processes on the shop floor
- The researcher - Production supervisors - Master scheduler	Review of the factors influencing poor transfer of required information between shop floor staff who are responsible to record accurate details of delays where further support is required	- Discussion - The researcher's observation - Questionnaire	Identifying specific factors that leads to inefficient response to delays on the shop floor
- The researcher - Machine operators - Managers - Product developers	Review of the factors influencing lack of effective communication between different functions of SMcorp Review of the factors influencing lack of effective communication between staff on the shop floor Review of the factors influencing lack of accurate skills and experience of shop floor staff	- Open-ended interviews - Questionnaire	Identifying the need for improving process on the shop floor Identifying the need for improving the communication between process planning and scheduling functions

A2. CPG Ltd – Original data collected

A2.1. Project initiation

A2.1.1. Summary of communications between the members of IPPS team

Participants	Event	Type	Results
- The researcher - IKT expert from CPG Ltd - The CPG Ltd representative - Production waste-related expert from CPG Ltd	Initial communication	- Discussions - Review meetings - E-mails	Identifying the CPG Ltd problem Clarifying the purpose of the IPPS project
- The researcher - IKT expert from CPG Ltd - The CPG Ltd representative	Developing and improving project proposal	- Review meetings - E-mails	First draft of project proposal
- The researcher - IKT expert from CPG Ltd - The CPG Ltd representative	Preparing the final draft of the project proposal	- E-mails	Final draft of the project proposal
- The researcher - The CPG Ltd representative	Reviewing the project proposal	- Review meeting	Agreement between the researcher and CPG Ltd
- The researcher - IKT expert from CPG Ltd - The CPG Ltd representative - Production waste-related expert from CPG Ltd	Identifying the key resources within the CPG Ltd with a view to create information	- Discussions - Review meetings - E-mails	Identifying potential functions Identifying data sources from different functions

A2.2. Project preparation

A2.2.1. Summary of communications between members of IPPS team and potential participants

Participants	Event	Type	Results
- The researcher - IKT expert from CPG Ltd - The CPG Ltd representative	Checking for available and accessible production waste-related data and information Identify individuals with	- Discussions - Telephone conversations (The key notes were	Identifying available data sources from different functions Identifying experts from

Participants	Event	Type	Results
- Production waste-related expert from CPG Ltd	problem-centred knowledge	sent to IPPS team in text format) - E-mails	potential functions Selecting experts with production waste-related knowledge
- The researcher - IKT expert from CPG Ltd - Production waste-related expert from CPG Ltd	Review of documentary evidence	- Discussions - E-mails	The basic production waste models
- The CPG Ltd representatives - Potential participants	Introducing the IPPS project aim and the members of the research team from IPPS to selected experts (Potential participants) Confirmation of interest in engaging in IPPS	- Telephone conversations - E-mails	Identifying the experts from different functions with production waste-related knowledge who are willing to participate in IPPS
- The researcher - IKT expert from CPG Ltd - Experts from participating functions	Introducing the objectives of the projects Identifying the available individuals and accessible data resources within CPG Ltd Explaining the benefits of the production waste-related data and individuals' experience for the success of this project	- Telephone conversations (The key notes were sent to IPPS team in text format) - E-mails	Confirming the experts who are willing to participate in IPPS New data and information
- The researcher - IKT expert from CPG Ltd - Production waste-related expert from CPG Ltd	Selecting and reserving dates and location of the IPPS meetings in form of design-shop	Discussions E-mails	Developing the design-shop agenda

Appendix B

Key ideas and themes from the implementation of EC-FIKT in the field

Key ideas and themes from the IPPS project at CPG Ltd

<table>
<tr><td colspan="2">I. EC-FIKT approach. The implementation of IPPS based on facilitated information and knowledge transfer</td></tr>
<tr><td>A. Outcomes of the application of EC-FIKT</td><td>The outcomes that were identified by individuals can be grouped into four key categories that are as follows:
1. Learning by experts
The role of the experts who participated in the project was to contribute their relevant knowledge. However, they felt that they benefited from involving in IPPS and the reasons are as follows:
- The project aimed at identifying root causes of CPG Ltd.’s problem. The outcome of this approach could reduce their workload. This emerged from comments that are as follows:
It’s the priority for our team to investigate high level of production waste. If we can find the reason behind it, we will invest our time on improving our service rather than investigating this issue
It helped us to identify the department responsible for it rather than investigating all the functions
- They did not consider feedback from shop floor staff as a valuable source of investigating the production waste. An examples of comments made by experts is as follows:
They just complain because they don’t want to understand how we operate and even when we try to tell them we are investing in production improvements we cannot satisfy them because they think we do not care about them
2. Learning by stakeholders
The internal stakeholders affirmed that their participation had positive impact on their understanding of the problem and it contributed to improving their knowledge base. They stated that their perception about staff experience has changed and they value investigating complaints from shop floor staff from different perspective. Some of their comments that were extracted from the data collected are as follows:
It helped our department to understand our staff perception
It clarified that what we considered very rare staff experience in terms of being unhappy about production waste is very common and also very important for the shop floor staff
3. New explicit resources became available
This approach creates the path to identifying and mapping root causes of a specific complex problem. For CPG Ltd, it was unexpected to see the factors it did not consider very important</td></tr>
</table>

	are the causes of many of its staff complaint which had been captured and stored without being reviewed. Moreover, it became evident that many of shop floor employees have reliable knowledge about production waste and redundancies that could help the CPG Ltd to address its complex problem. Service expert's comment about this issue was as follows: *CPG Ltd believed only a very few number of its staff might be dissatisfied with the organisation just because they had bad experience with the shop floor routines and now we understand how this assumption created such a gap in our analysis* 4. New communities of interest They found this opportunity to learn that their colleagues had experienced the same issues in regards to not feeling comfortable about communicating their experience with managers before this project for the reason that the value of their experience had not been explicitly verified. Summary of one of the comments is as follows: *I always thought if I complain about the new software and how it has increased the number of employees' errors and the amount of time we need to correct the mistakes; it might be understood as my lack of experience or just complaining about colleagues' work. Now it is clear that it has an influence on the company too, I can discuss my ideas freely with my manager*
B. Mapping the root causes of the complex problem	The process of developing charts and models that assists mapping the root causes of production waste and redundancies with CPG Ltd is as follows: Identifying factors that might have negative impact on communication between diverse internal stakeholder groups This let to simplifying the complex problem to a significant extent and better understanding of its employees needs and perception of CPG Ltd. Some of the comments from the experts that highlights this realisation are as follows: *This has been a necessary and reliable way of extracting staff knowledge about our manufacturing company* *This truly creates a new path to improving production*
C. Participants	Participants were selected by the CPG Ltd analyst and managers of relevant departments. In terms of the selection of experts, management was aware of the value of the knowledge and experience of individuals from different departments, therefore facilitated their participation as much as it was required
D. Type of information and knowledge	Information and knowledge about production waste and redundancies of different departments and employees were captured from experts identified root causes of the problems

Key ideas and themes from the IPPS project at CPG Ltd

E. Communication technologies	Information and communication technologies were only used to support the preparation and running IPPS project. E-mail in particular was only used to organise every meeting, share documents related to running the project or documentary evidence. Data projector was used, occasionally
II. Other approaches. The limitations of existing approaches to IPPS in comparison with the application of EC-FIKT	
A. Demands from participants	The IPPS project at CPG Ltd used the comments from employees who were willing to participate in IPPS meetings The participants were dedicating their time and effort into investigating the reasons behind high level of production waste and redundancies, in particular because of the pressure from regulatory bodies and the penalties this manufacturing company has been receiving, therefore their participating in this project was considered part of their job and mission This project only required insignificant time of experts and for the same reason which was the pressure from regulatory bodies and the penalties this manufacturing company has been receiving, their participation in finding the root causes of production waste and redundancies was seen very important for the manufacturing company
B. Collaborative environment	There is no evidence in the data collected to suggest that the IPPS project was limited by the ability of participants to contribute their knowledge
C. Motivation	A presentation was given to CPG Ltd at the end of the project in an attempt to relate EC-FIKT outcomes to critical success factors for the manufacturing company. The CPG Ltd representative discussed the value of the IPPS project. One of his comments is as follows: *It helped us to understand root causes of our problem, it helped us to recognise how we have been investing on improving our manufacturing according to productivity when we neglected understanding the ideas of for example not knowing how redundancies or production waste happens*
III. Group dynamics. EC-FIKT and leading group dynamics	
A. Trust	Only at the beginning of the IPPS project at CPG Ltd there was some resistance to openly discuss the unsuccessful work that has been done to understand high level of production waste and redundancies or to freely clarify that such a complex problem exists. This issue was determined and addressed which has become one of the key steps of EC-FIKT. Since this issue was clearly eliminated, CPG Ltd introduced this project as trustworthy to the internal stakeholders which allowed them to openly share their knowledge and discuss about CPG Ltd and its problem, during the rest of the IPPS process.
B. Communication	The observation and notes taken during the IPPS meetings show that participation was not restricted to experts' contributions. Internal stakeholders contributed actively to the discussions, even when it was only to raise questions and concerns in the search for experts' answers and support.
C. The role of leader(s)	From the beginning of IPPS project at CPG Ltd, the researcher familiarised himself with CPG Ltd area of work and its functions experience through valuable resources which are as follows:

Key ideas and themes from the IPPS project at CPG Ltd

	- Reviewing available literature on the topics of CPG Ltd background, collaboration with diverse internal stakeholder groups about manufacturing - Reviewing documentary evidence provided by CPG Ltd - Conducting the field research at the CPG Ltd that facilitated attending staff training and conducting number of open-ended interviews with experts This familiarisation process assisted the researcher to successfully run the IPPS meetings. The CPG Ltd representative who was an expert in analysing data also had the collaborative leader role. His experience and connection with internal stakeholders helped the IPPS project in terms of identifying and engaging experts with problem-centred knowledge from relevant department. His area of expertise also contributed to the accuracy of the data analysis.
IV. Evaluation. Evaluation of EC-FIKT as an approach to IPPS	
The IPPS project was evaluated based on getting feedback from the participants at two levels that are as follows: 1. At the organisational level The CPG Ltd highlighted the value of this project for this manufacturing company in terms of productivity 2. At the individual level The researcher investigated the value of IPPS project for the individuals mostly at the end of the IPPS meetings or open-ended interviews. All the participants from different departments and experts found this project beneficial for understanding CPG Ltd root causes of production waste and redundancies. They also found this project created an opportunity for them to have a better and more accurate communication with different departments and also within each department	